Air & Space

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Smithsonian Institution

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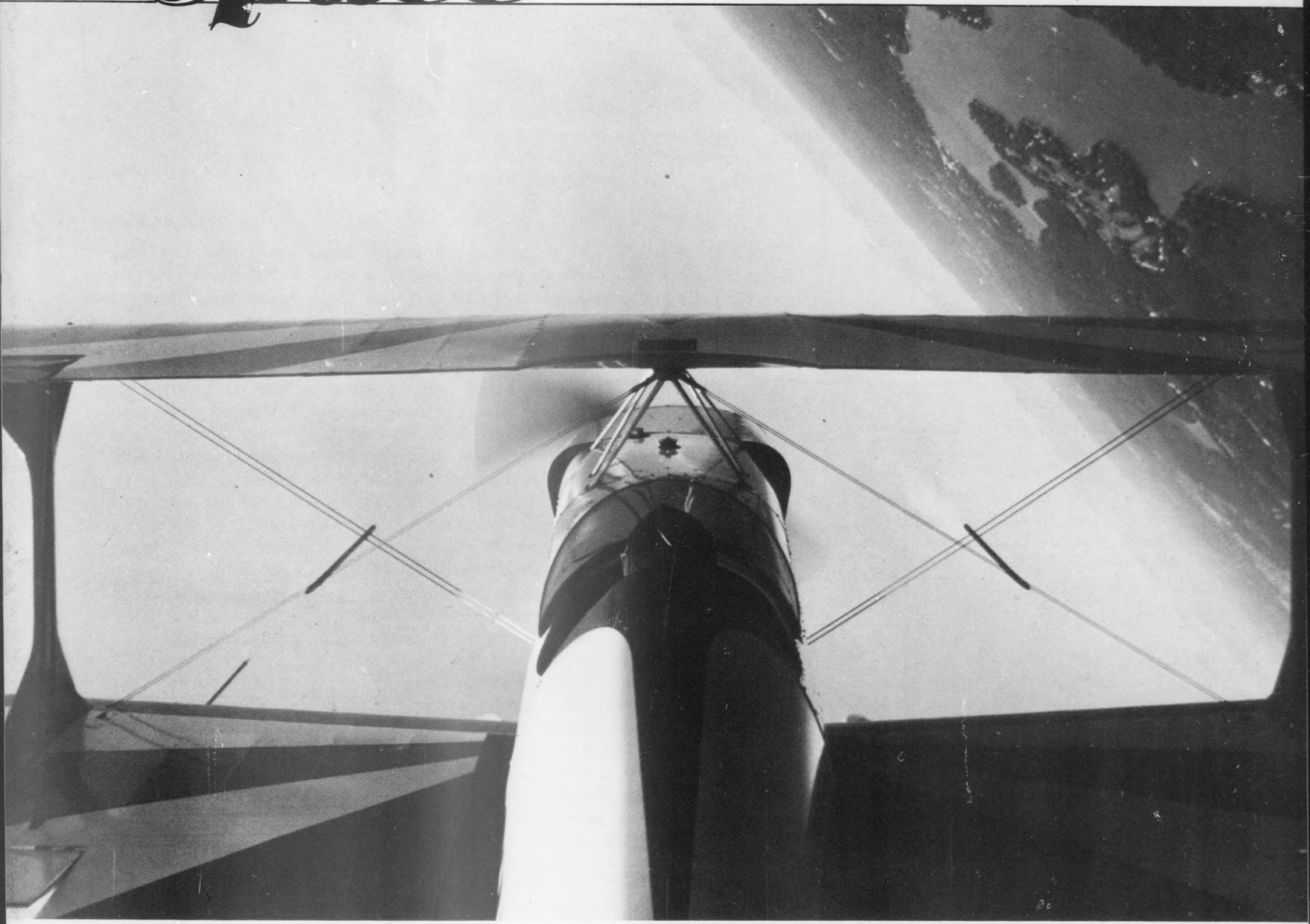

Aer·o·bat·ics *n pl but sing or pl in construction* [blend of *aer-* and *acrobatics*]: spectacular flying feats and maneuvers (as rolls, loops, spins, and dives), not necessary to normal flight, voluntarily performed in aircraft—**aer·o·bat·ic** adj

Aerobatic flight was an inevitable result of the curiosity and daring of the first few hundred airplane pilots—pilots curious about the possibilities of this wonderful new invention, puzzled by mysterious accidents and harrowing close calls, full of questions about aerodynamics, flight control, and the effects that the departure from straight-and-level flight would have on their bodies and aircraft. Further developed and tempered in the heat of the world's first great air war, aerobatics became the carnival stock-in-trade of the barnstormer and an important element of military flight training.

Today, exhibition pilots thrill millions of air show attendees annually with aerobatic performances. And for thousands of recreational aviators—like the pilot rolling his Pitts S-2A biplane, above—aerobatics is an exhilarating participant sport. Whether in the highly structured and intensely competitive arena of the World Aerobatic Championships, or simply flying for fun, the aerobatic pilot uses his airplane as an artist's tool to create grace and symmetry in the sky from the raw materials of lift, thrust, drag, and gravity. Not "stunt" flying, but precision flying in which excellence is the goal, aerobatics is the aerial counterpart to ballet and gymnastics, aviation's poetry in motion. **More, Page 3.**

SCAN

For brevity, the National Air and Space Museum is often referred to in these pages as NASM. The National Aeronautics and Space Administration is NASA.

MUSEUM HOURS
Museum hours after Labor Day (September 4) are 10 a.m. to 5:30 p.m., seven days a week. The Museum is closed Christmas Day.

SPACEARIUM SHOP
A price list of all aerospace items available by mail through NASM's Spacearium Shop may be obtained on request by writing to Room P701, National Air & Space Museum, Smithsonian Institution, Washington, DC 20560.

FREE ASTRONOMY LECTURES
FOR SCHOOL GROUPS
NASM's Albert Einstein Spacearium presents "Exploring Stars and Planets" lectures to school groups on Wednesdays from 11:30 a.m. to noon. These lectures are free, but are by appointment only. If you are planning a class trip to NASM, make your reservations for this presentation by calling (202) 381-4056.

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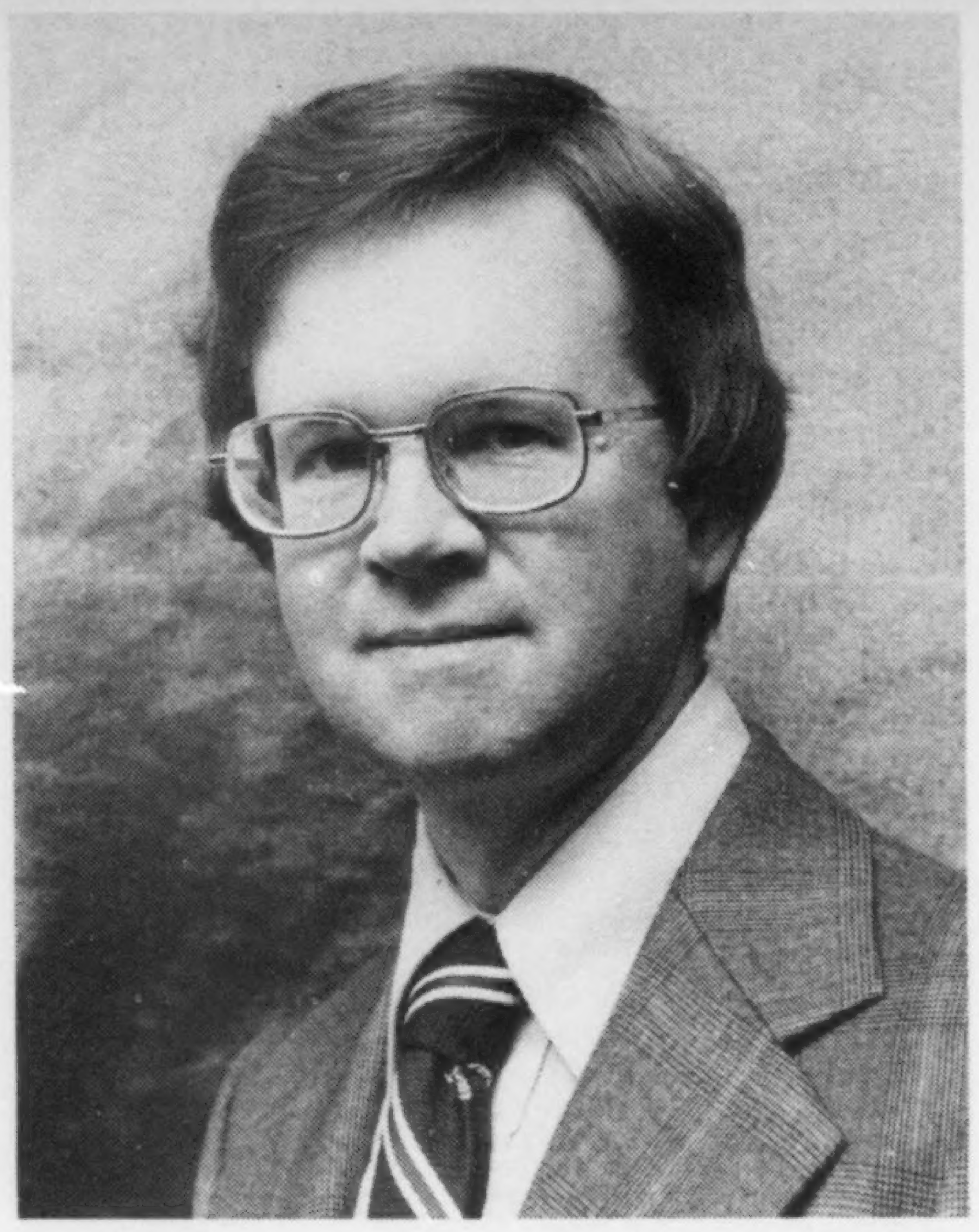
Briefing



Noel W. Hinners
Director, NASM

The array of articles in this issue demonstrates that there is greater variety in air and space activity—both past and present—than many people are aware of. As you read, you might want to consider some "peripheral" aspects of these activities that, while seemingly remote from the main topic, may be just as important as what appears on the surface.

One cannot help but be thrilled by the artistic aerobatic performances frequently seen in exhibition flight, and to marvel at the finely-tuned interplay between human and machine. The combination of skilled flying, superior machines, and the challenge of competition surely are significant factors in leading some youthful spectators to seek careers in aviation. Most of these careers do not involve actual piloting, because the required number of commercial pilots is relatively small (but increasing right now as the use of business aircraft rapidly expands). However, it takes many hundreds of thousands of engineers, production workers, administrators, flight controllers, and other skilled specialists to build and maintain aircraft, produce new ones for the future, design instrumentation, operate airports, and provide innumerable associated services. And almost anyone can learn to fly and become a member of that part of the general aviation community that flies largely for fun and recreation. It has been estimated that about 140,000 Americans started flight training last year, with about half expected to earn a private pilot license.

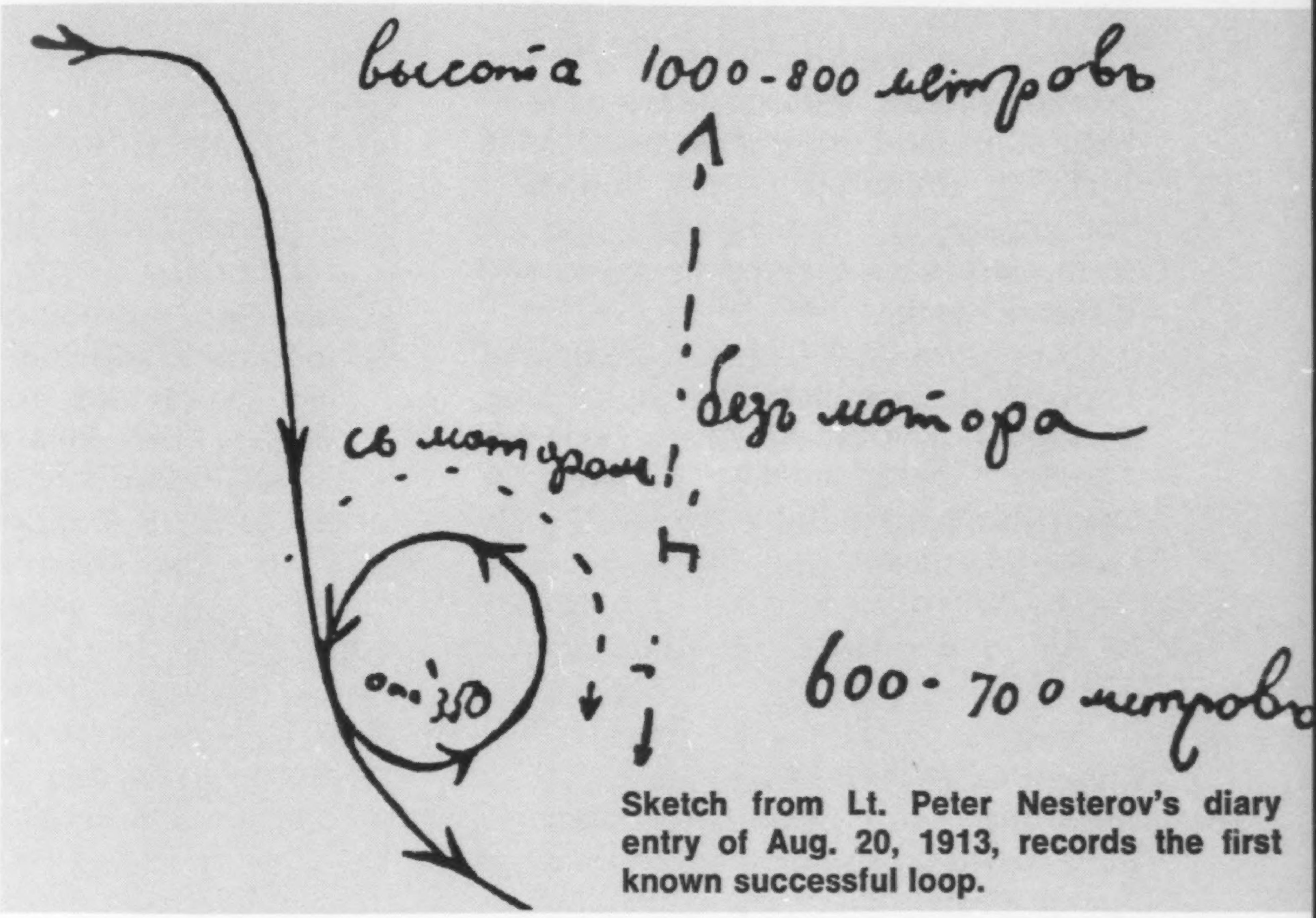
The aerial photography feature sheds new light on a topic we usually associate with topographic mapping, geological surveys, exploration, and land-use studies. Much of the camera technology and photointerpretive techniques so useful for civil work derived from military developments, either wartime target identification, damage assessment, or other types of reconnaissance. Similarly, there has been an evolution of aerial photography into orbital photography, again largely oriented towards national security, but having tremendous impact on civilian life. Such programs as the Lunar Orbiter (which in 1964-1965 took the site survey photos of the Moon for the Apollo program) and the Landsat and Seasat types of satellites are paving the way for practical, everyday applications of remote sensing.

The Pioneer 11 mission to Saturn was a gamble that has proven to be a great success. Nobody was sure, back in 1973, that Pioneer 11 would be able to make it through the asteroid belt, survive Jupiter's strong radiation, continue to work for six years, and then survive passage through Saturn's ring system! But it has, and in addition to providing new planetary data, Pioneer 11 will improve the two Voyager missions, which rendezvous with Saturn in 1980 and 1981. It also has convinced NASA planners that Voyager 2 can safely follow the path of Pioneer 11, thus putting Voyager 2 on a trajectory to encounter Uranus in 1986.

Finally, consider the pioneering research being done with the Smithsonian Astrophysical Observatory's MMT (Multi-Mirror Telescope). Ground-based telescopes are reaching the practical limits of size. It's hard to get a good, stable optical surface on a telescope mirror much over four or five meters in diameter; even then, atmospheric effects soon become the limiting factor. However, there is an ingenious way to beat the size problem by ganging a series of smaller mirrors together in a way that effectively equals the light-collecting area of a much larger, but structurally impractical, single mirror. The MMT, already obtaining first-class scientific data, is an experiment in itself, to see just how well astronomers can control the six individual 1.8-meter (72-inch) mirrors (surplus from a military program) so that they work as a "team." It may well be that all future large ground-based telescopes will use the MMT approach.

Test pilot Celestin-Adolphe Pegoud pioneered aerobatic maneuvers in a Blériot XI monoplane (above). In September, 1913, he attempted a "side somersault" (roll) at Buc, near Paris (left).

AEROBATICS!



Sketch from Lt. Peter Nesterov's diary entry of Aug. 20, 1913, records the first known successful loop.

On Aug. 20, 1913, the airplane was not yet 10 years old, but Lt. Peter Nesterov of the Imperial Russian Air Service was about to attempt a feat never before accomplished in an airplane, and probably seldom, if ever, by the birds. Nesterov climbed slowly to 1800 feet above the Syretzk Aerodrome near Kiev in his 70-hp Nieuport monoplane. Pushing over into a steep dive to gain speed, he then arced up into the sky and performed the first successful complete loop.

Today, the Federal Aviation Administration defines aerobatic maneuvers as those in which an aircraft exceeds 30° pitch above or below the horizon, and/or banks more steeply than 60°. By that definition, aerobatics began as early as 1905, when Daniel J. Maloney performed his "corkscrew twist" (probably a kind of roll) in a Montgomery tandem-wing glider dropped from a balloon. By 1910, a few daring pilots, such as Walter Brookins of the Wright Fliers exhibition team, were making steeply banked turns and spiral dives that were as controversial as they were thrilling.

All aerobatic maneuvers are variations upon, or combinations of, dives, climbs, turns, and four basic maneuvers—the loop, roll, spin, and hammerhead or stall turn. These basic maneuvers, plus simple variations, were accomplished before the end of the airplane's first decade.

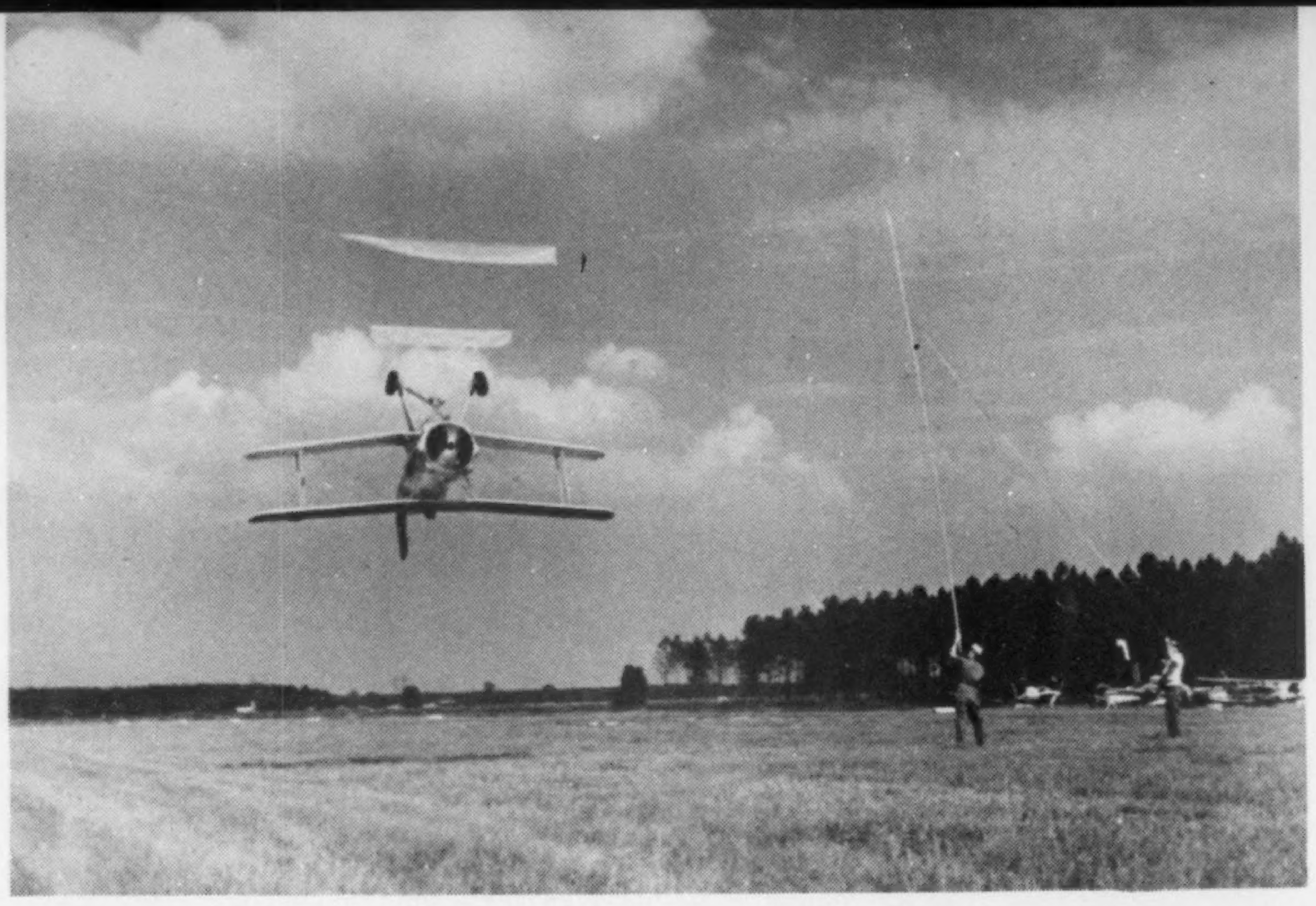
In 1912, W. B. Rhodes-Moorhouse's first attempt at a tailslide in a Blériot resulted in a hammerhead turn. Lt. Wilfred Parke, in August of that year, solved the problem of spin recovery with seconds to spare and made the first deliberate recovery from a spin (called "Parke's dive" for a time).

But 1913 was the big year in aerobatic history: In June, the first aerobatic match was held at Juvisy, near Paris. On Aug. 20, Nesterov flew the first loop. In October, a French audience witnessed the first demonstration of precision formation flying, the "Ballet Aerien." Celestin-Adolphe Pegoud, a noted aerobatic pioneer and Blériot test pilot, may have mastered the roll that year. And on Nov. 25, American exhibition pilot Lincoln Beachey, prodded out of retirement by news of Pegoud's successes, flew the first loop in the United States.

With the onset of World War I, aerobatics became deadly serious. Combat pilots developed new maneuvers, such as the Immelmann turn (a half loop followed by a half roll recovery) in an effort to outmaneuver their enemies. The Immelmann turn, named for German ace Max Immelmann, actually was invented before the war. Gustav Hamel and Pierre Chantaloup demonstrated the maneuver at Hendon, England, in December 1913. Immelmann himself usually employed the *chandelle* (a steep climbing turn), another maneuver Hamel originated at Hendon in 1913.

At the beginning of the war, English and American pilots were prohibited from engaging in aerobatic flight on the grounds that it caused accidents. A few of these pilots, realizing that *lack* of solid aerobatic training actually caused more accidents and left Allied pilots ill-prepared for combat, secretly taught themselves. (Lt. Eddie Rickenbacker, grounded 30 days for spinning, eventually became America's most-decorated World War I ace.) Eventually, the Royal Flying Corps and the U.S. Army Air Service recognized the

Beverly "Bevo" Howard (right) thrilled audiences with his inverted ribbon-cutting act (left) from 1946 until 1971, when he was killed while performing. The Howard family had his Bücker 133 Jungmeister rebuilt and donated it to NASM, where it hangs inverted in the Exhibition Flight gallery. Designed in 1936 and widely used as an advanced trainer for the fledgling Luftwaffe, the Jungmeister was one of the most significant aerobatic designs ever built. Jungmeisters were favorites of several exhibition pilots noted for extremely low-level aerobatics, and won many national and international meets.



urgent need for aerobatic training, and courses like "Basic Battle Acrobacy and Trick Flying" became mandatory for fighter pilots.

After the war, barnstormers spread aviation across America, using aerobatic stunts and other sensational aerial tricks to drum up paying audiences and passengers. But as sport and art form, aerobatics yielded to speed and distance flying.

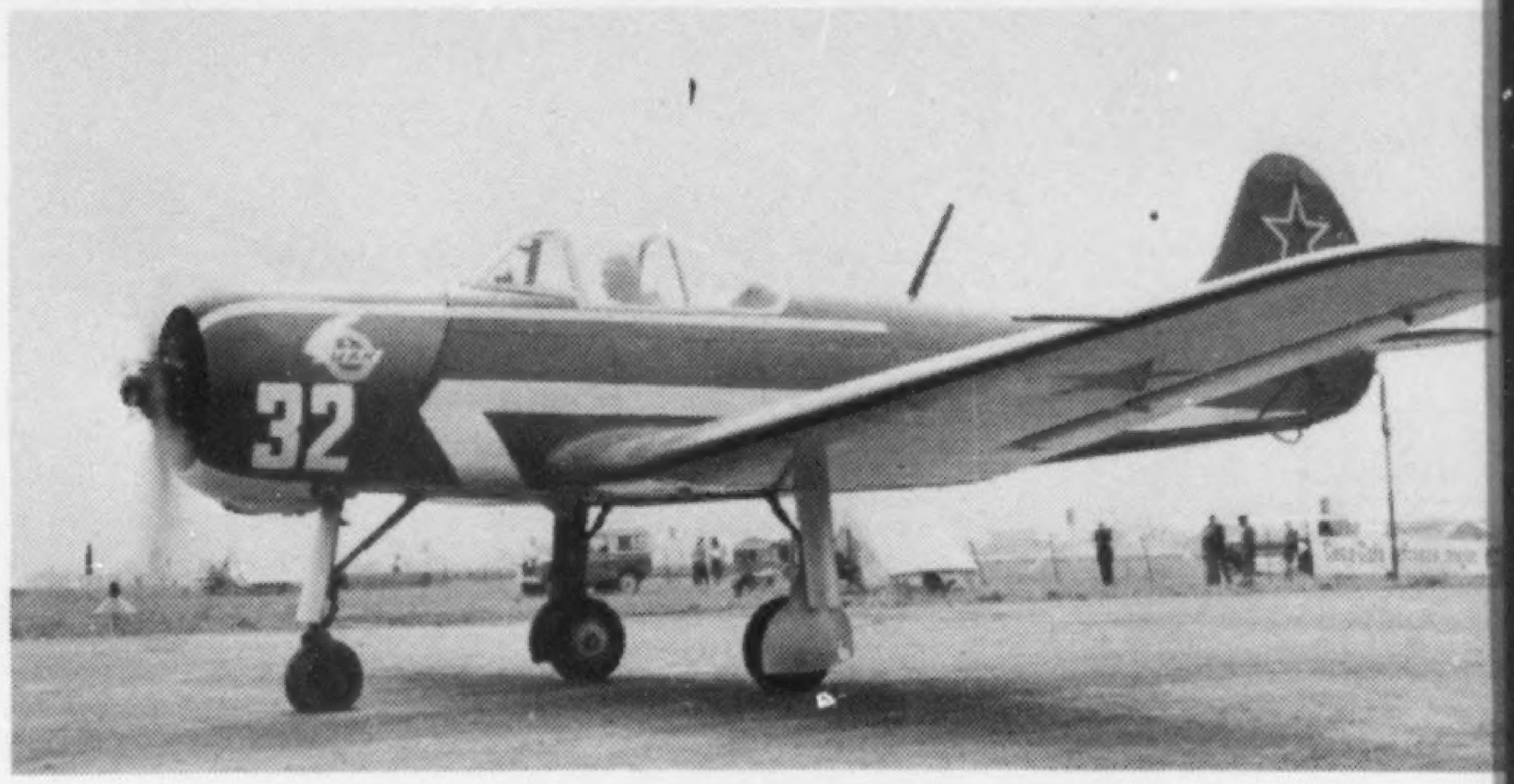
During the 1920's, aerobatics figured importantly in military research flying. In 1924, U.S. Army Air Corps Lt. James "Jimmy" Doolittle flew a series of aerobatic flight tests in specially instrumented aircraft. Data gathered from these flights contributed significantly to the development of future fighter aircraft.

Pegoud's 1913 repertoire had included an inverted half-loop or "English bunt," but no pilot was known to have flown a complete inverted loop. Scientists and seat-of-the-pants aviators alike speculated that inverted or "outside" maneuvers could be fatal.

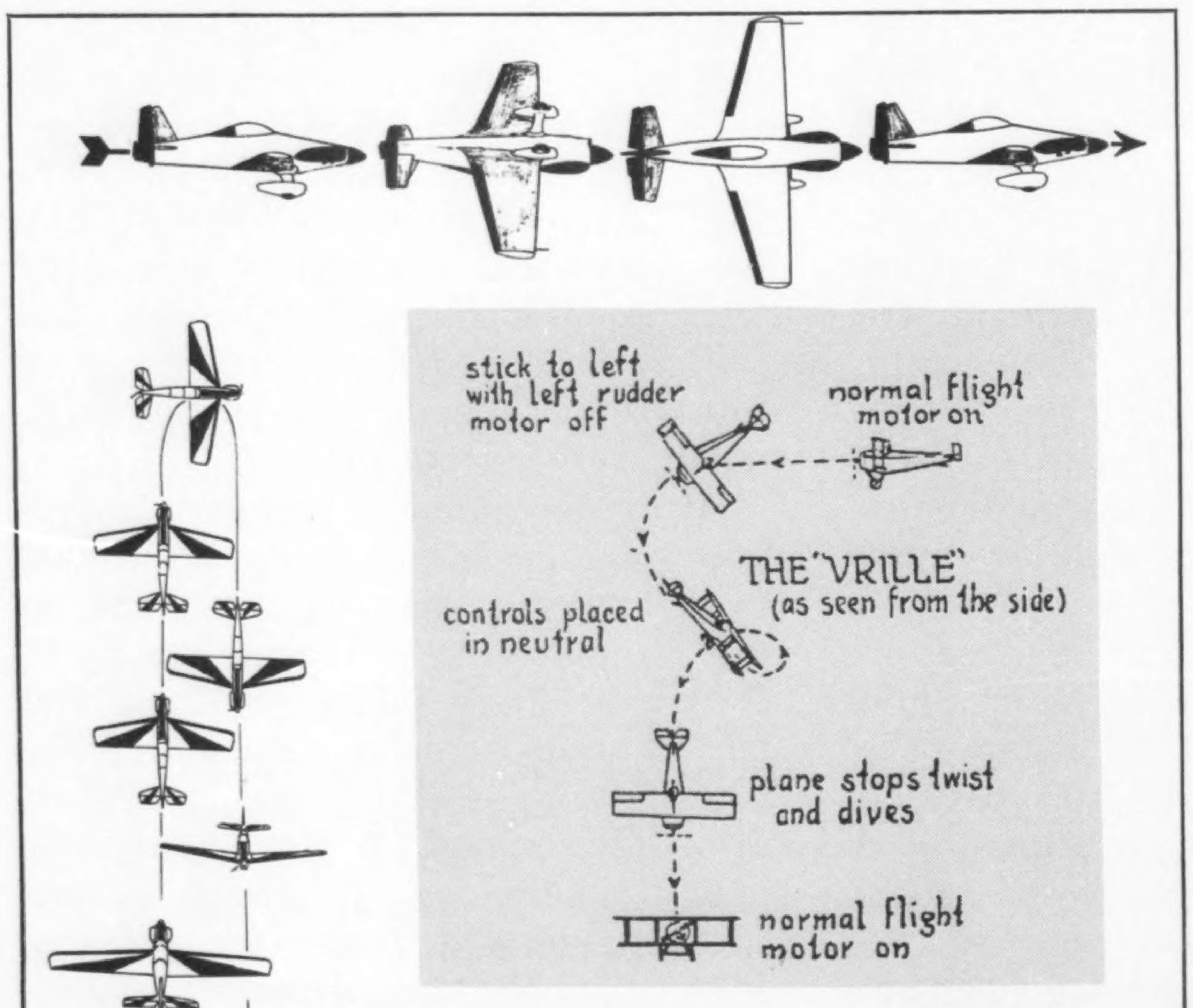
On May 27, 1927, Doolittle pushed a Curtiss P-1B Hawk over into a complete outside loop high above McCook Field, outside Dayton, Ohio. Despite temporary discomfort, neither Doolittle nor the Hawk suffered any lasting effects. Soon afterward, U.S. Navy Lt. Al Williams began extensive aerobatic research flying, and later was awarded the Distinguished Flying Cross. Both Doolittle and Williams became popular aerobatic exhibition pilots; Williams' famed Grumman G-22 *Gulfhawk II*, a frequent air show attraction from 1936 through 1948, now belongs to the NASM collection.

The 1930's saw rapid growth in aerobatics, both as a form of exhibition flight (especially at very low altitudes) and as a competitive sport. Aerobatics had been very popular in Europe since the signing of the Versailles Treaty. In Germany, the pilots of the future Luftwaffe were training in sport flying clubs and all flying had government sanction. The competition held at Zurich in August 1927 was the first of several pre-war international aerobatic competitions that drew the finest European and American aerobatic pilots.

During World War II, civilian aerobatic flying virtually ceased, while combat aerobatics—now a basic element of war in the air—once again



The Soviet Yak 18PM (above) and the Czech Zlin 526A Trener Master (below), which swept the 1966 and 1968 World Aerobatic Championships respectively, both come from a long line of successful aerobatic designs.



The four basic aerobatic maneuvers are the roll (top), the loop (pages 8-9), the hammerhead or stall turn (left), and the spin, called the "vrille" (French for spin) in this excerpt from a 1918 U.S. Army Air Service training manual (above).

Betty Skelton popularized the diminutive Pitts Special (below, right) by winning the NAA Womens Division title from 1948 through 1951 in her *Little Stinker.* In 1972, Charlie Hillard (right) and Mary Gaffaney (below, left), flying improved versions of the highly successful design, became Individual World Champions at Salon-en-Provence, France. A Pitts Special hangs in NASM's Exhibition Flight gallery.

pitted enemy pilots against each other in deadly contest.

Since the end of World War II, sport aerobatics has enjoyed a renaissance, especially in Communist Europe and the Soviet Union, with their state-supported flying clubs, and in the United States and western Europe.

In August 1960, the Czechs hosted the first World Aerobatic Championships since the Coupe Mondiale of April 1938, held at St. Germain, France. The World Championships have been held every second year since, each time in a different country.

Next year, the tenth World Aerobatic Championships will be held on Wittman Field in Oshkosh, Wisconsin, August 17-30—the first time the Championships have been held off the Eurasian continent. (For more information, contact World Aerobatics '80, Box 229, Hales Corners, WI 53130.)

What of the future? Sport aerobatic pilots talk of maneuvers plotted but yet unflown, such as the knife-edge loop—i.e., a loop flown by an airplane on its side. Perhaps one day soon (at the 1980 World Championships?) a skillful pilot in a powerful new aerobatic design will succeed where others have failed, adding another spectacular figure to the choreography of the skies.

Four-time National Aerobatic Champion Leo Loudenslager's face shows the strain of a high-g vertical outside snap roll. Human tolerance to high sustained g forces is one of the main limiting factors in aerobatics.

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Exhibition Flight, compiled by Robert C. Mikesh and Claudia M. Oakes. Washington, DC: Smithsonian Institution Press, 1973. 53 pp. Features aircraft in the NASM collection.

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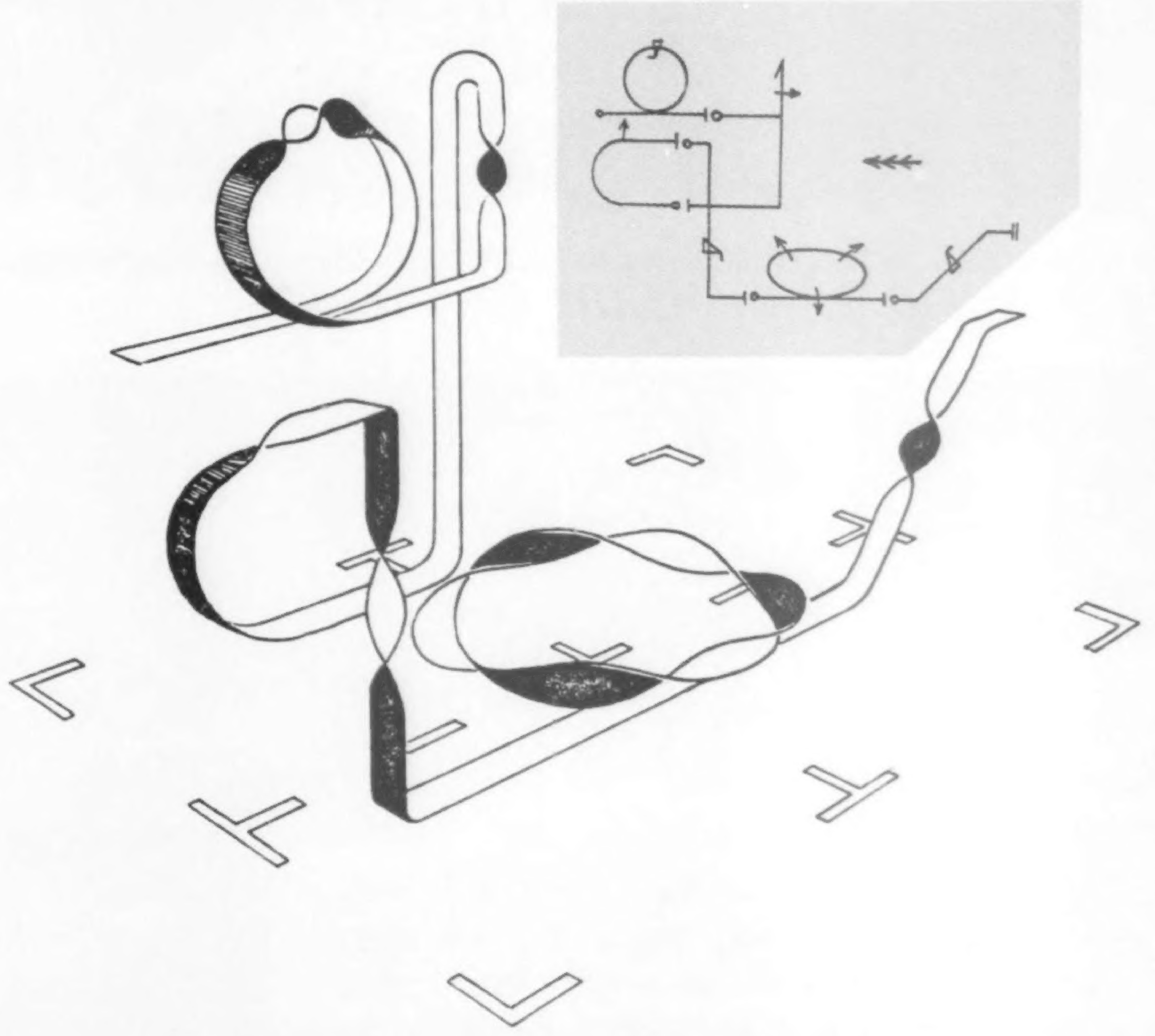


Competition Aerobatics

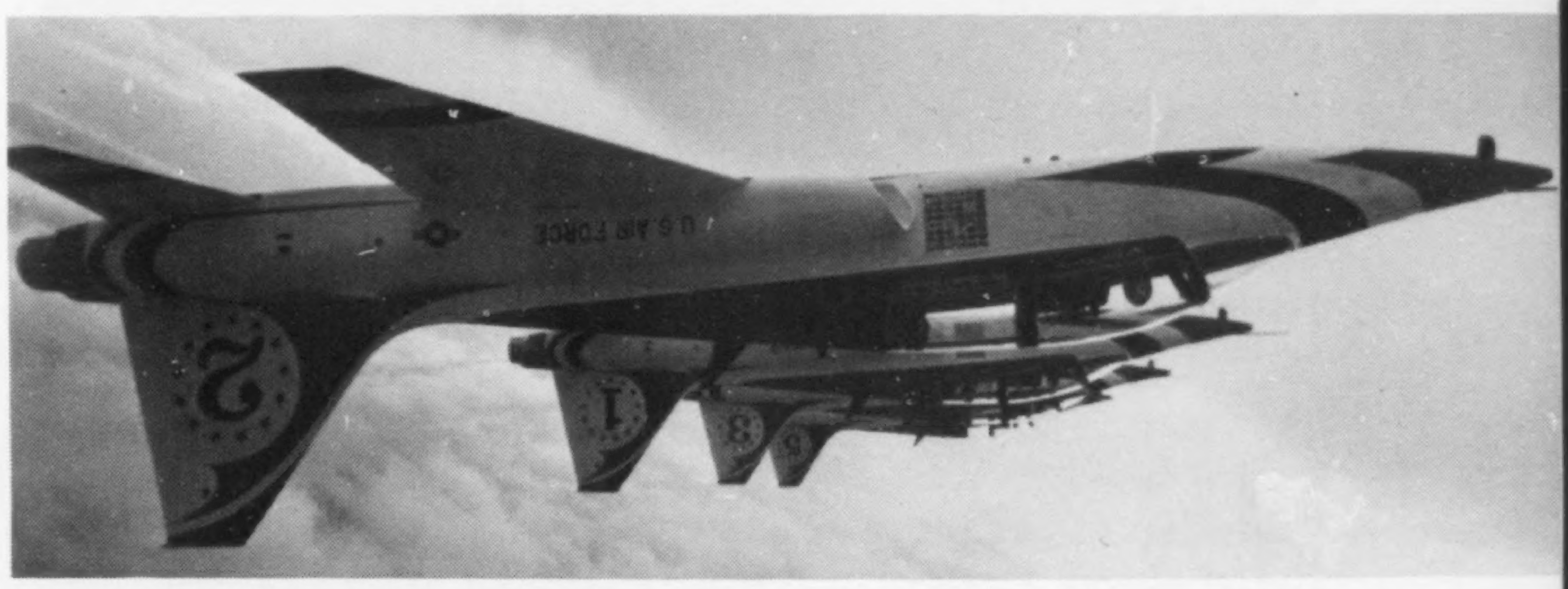
International aerobatic competition consists of four parts: two compulsory sequences (one known six months in advance, the other unknown until the competition date), and two free-style sequences, the second open only to finalists.

Contestants must stay within a "box" of airspace 800 by 1000 meters (2625 by 3280 feet) wide, extending from 100 to 1000 meters (328 to 3280 feet) above the ground. Pilots must complete their maneuvers in a prescribed time limit.

All countries entered in the competition contribute judges to the judging panel. The high and low scores are dropped and the remaining scores averaged.

The Aresti Aerocryptographic System (shaded diagram at upper right, above), named for its inventor, Col. José Aresti of Spain, provides a uniform basis for scoring the individual maneuvers of each contestant. Every maneuver can be assigned a possible perfect score weighted according to difficulty.

Each maneuver is represented by a symbol easily recognizable to the pilot. The symbols are linked to show the pilot and judges the proper sequence of the maneuvers. The pilot follows a copy of the Aresti sequence card clipped to the aircraft instrument panel.

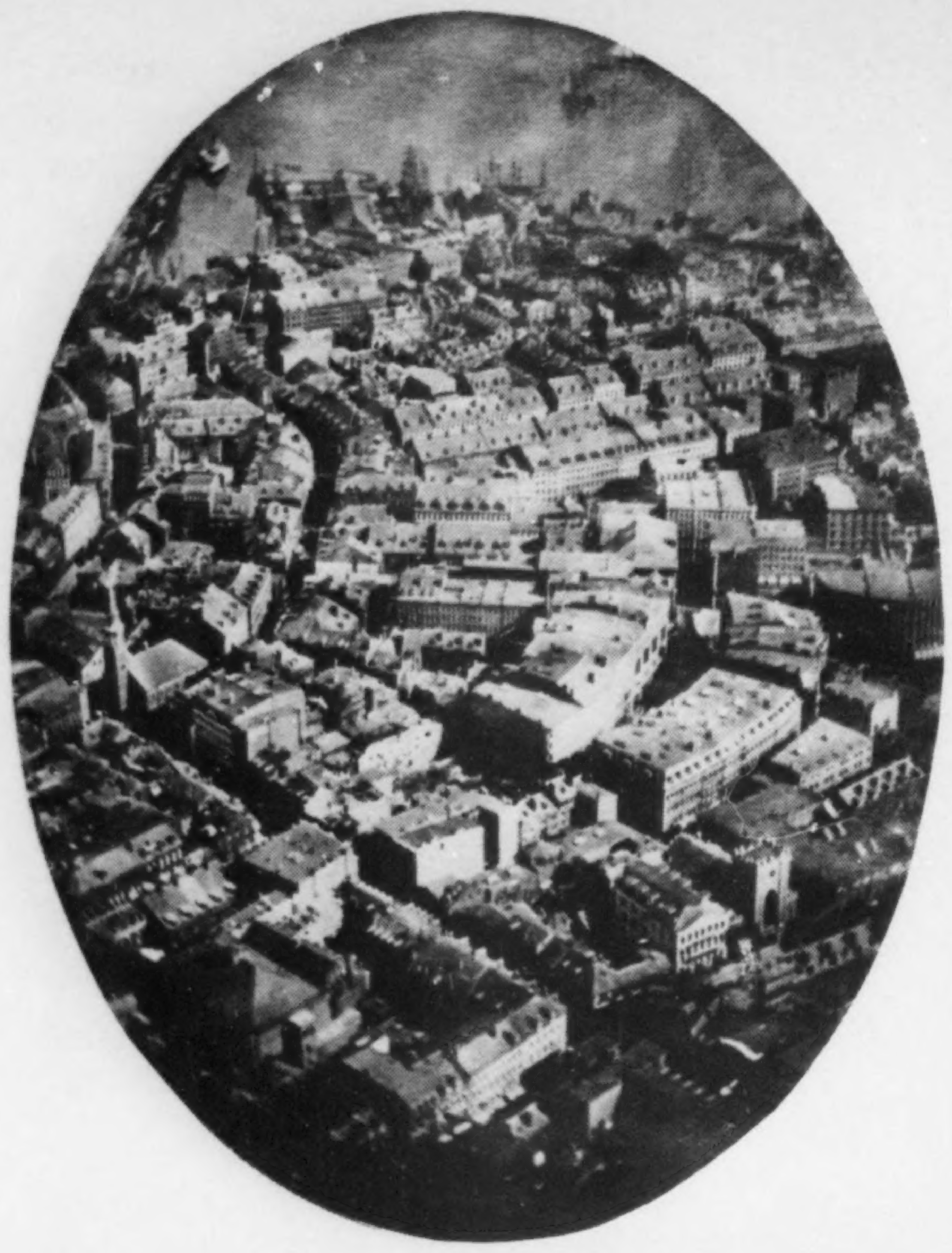


Blue Angels and Thunderbirds

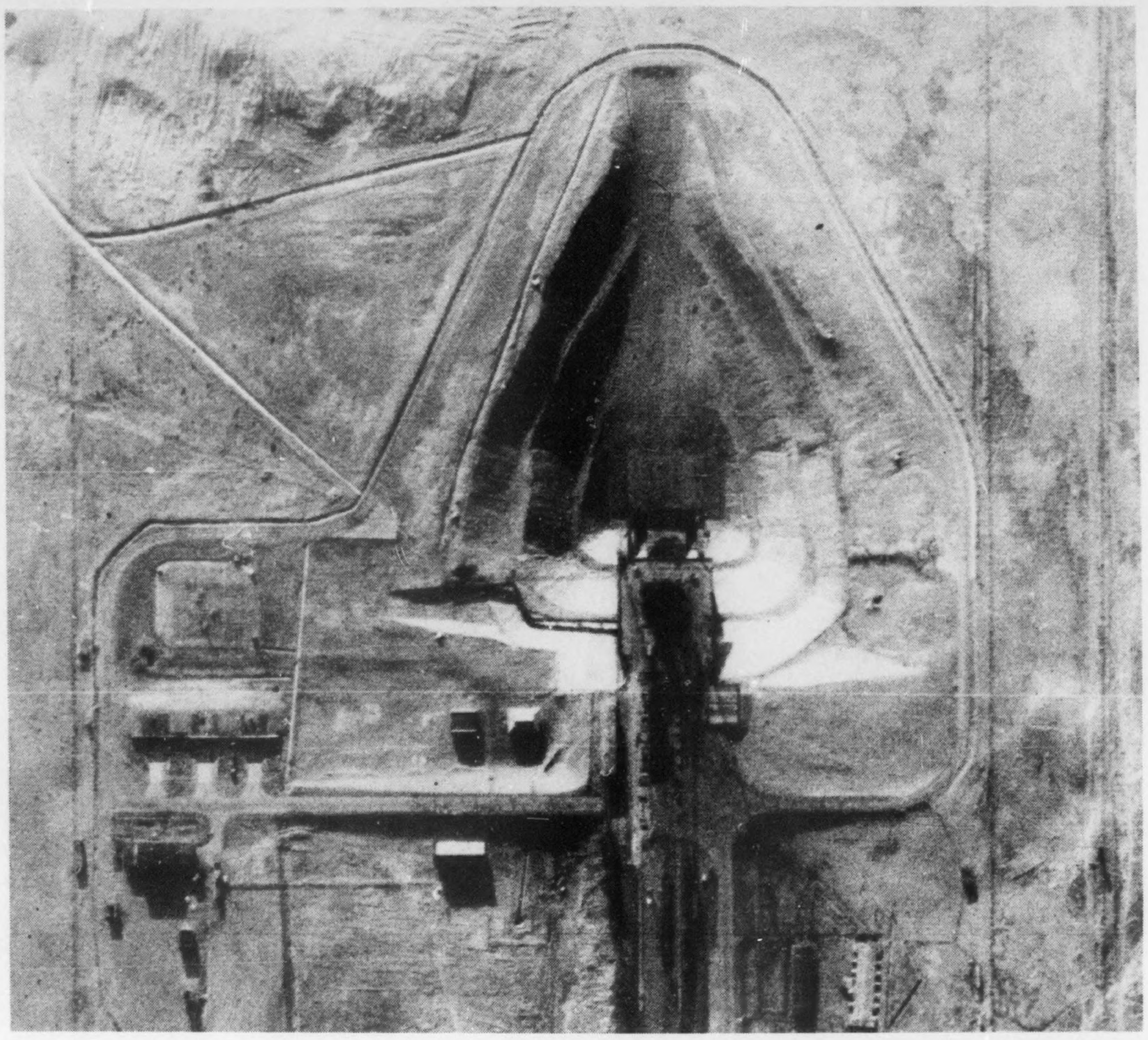
Dozens of solo and team aerobatic acts tour the U.S. annual air show circuit. Perhaps the best known are the Blue Angels (USN Precision Flight Demonstration Squadron) and the Thunderbirds (USAF Air Demonstration Squadron), which perform precision formation aerobatics, based on tactical maneuvers, at scores of air shows across the country. The Blues and Thunderbirds continue a tradition begun in 1928 at the National Air Races, where the U.S. Navy's Sea Hawks and the U.S. Army Air Corps' Three Musketeers made their debut.

The Blue Angels, formed in 1946, now fly the McDonnell-Douglas A-4 Skyhawk II, a carrier-based jet light attack bomber (left, above). [A USN A-4C is displayed in NASM's Sea-Air Operations gallery.] The Thunderbirds, formed in 1953, fly the Northrop T-38A Talon supersonic jet trainer (top).

For information on the Thunderbirds' 1980 air show schedule, write to the USAF Air Demonstration Squadron, Box 9733, Nellis AFB, NV 89191. The Blue Angels' 1980 schedule may be obtained from the USN Flight Demonstration Squadron, NAS Pensacola, FL 32508.



This aerial view of Boston, taken by James Wallace Black in 1860, is one of several pioneering aerial photographs displayed in "Our Beautiful Earth: The View from Air and Space," a special exhibit in NASM's Flight and the Arts gallery until Christmas, 1980. The exhibit features the work of noted photographers Robert Buckman, William Garnett, Georg Gerster, and George Hall, as well as images made by LANDSAT and other spacecraft. Photo courtesy International Museum of Photography, George Eastman House, Rochester, NY.



1 Two firsts in space began here.

AERIAL PHOTOGRAPHY

Adding a New Dimension to History

On October 13, 1860, photographer James Wallace Black ascended twice above Boston in the gas balloon *The Queen of the Air,* piloted by aeronaut Samuel Archer King. Drifting 366 meters (1200 feet) over the city, Black exposed six photographic plates. One of the photographs survives today; with the possible exception of a very faint simple glass positive made by the French photographer Nadar 80 meters above the Val de Bièvre in 1858, it was the first successful aerial photograph.

In the July 1863 issue of *The Atlantic Monthly,* Oliver Wendell Holmes —a photographer himself, and a pupil of Black's—described the historic photograph, noting that "Boston, as the eagle and the wild goose see it, is a very different object from the same place as the solid citizen looks up at its eaves and chimneys. . . ." After identifying and describing the principal landmarks in the photograph—i.e., *interpreting* it—Holmes concluded, "As a first attempt it is on the whole a remarkable success; but its greatest interest is in showing what we may hope to see accomplished in the same direction."

Since Holmes wrote those words, millions of photographs of the Earth have been acquired from the air and space. Most have been taken for purposes of aerial reconnaissance—for gathering military intelligence, mapping and charting, or analyzing natural resources.

But this vast collection of aerial photographs also constitutes an unexploited and irreplaceable historical legacy. Over 500,000 cans of aerial photo film are stored in film vaults in the Washington, DC area. The film, acquired primarily by U.S. Army, Navy, and Air Force missions, covers the period from World War I to the present; it is available to serious researchers with the proper credentials.

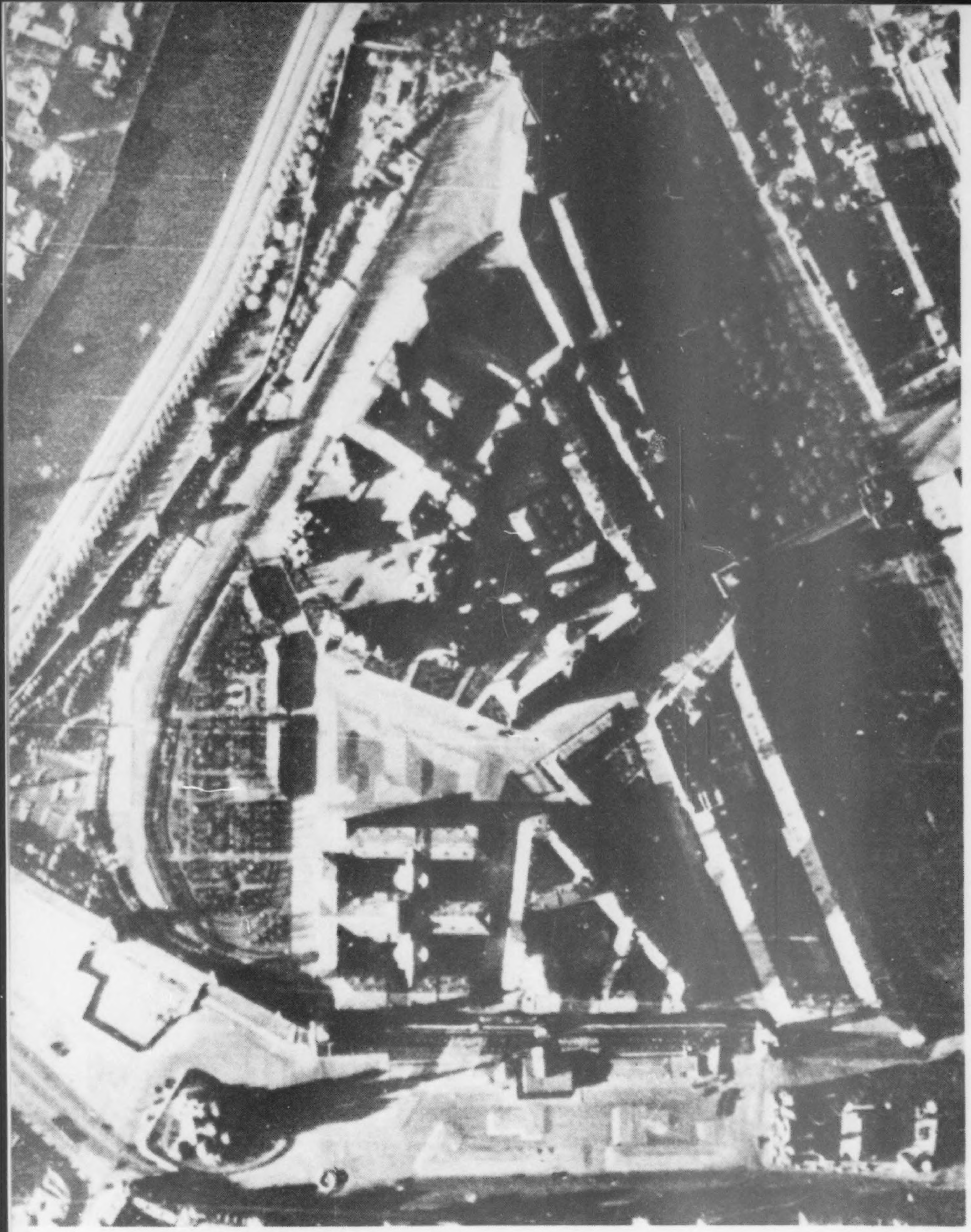
This rich treasure trove of photo documentation has much to offer historians. A photograph "freezes" a moment in time; unlike personal recollections, the contents of photographs don't change with time. They can be analyzed again and again, each time with a different objective in mind.

Photo interpretation is a skill involving sophisticated scientific techniques artfully applied; however, even though aerial photography has been practical for over 100 years, relatively few people have been trained to interpret the results. At the university level, courses in photo interpretation, if offered at all, traditionally are taught in the science departments, and focus on the use of aerial photos in resource analysis or mapping, rather than as a tool of history.

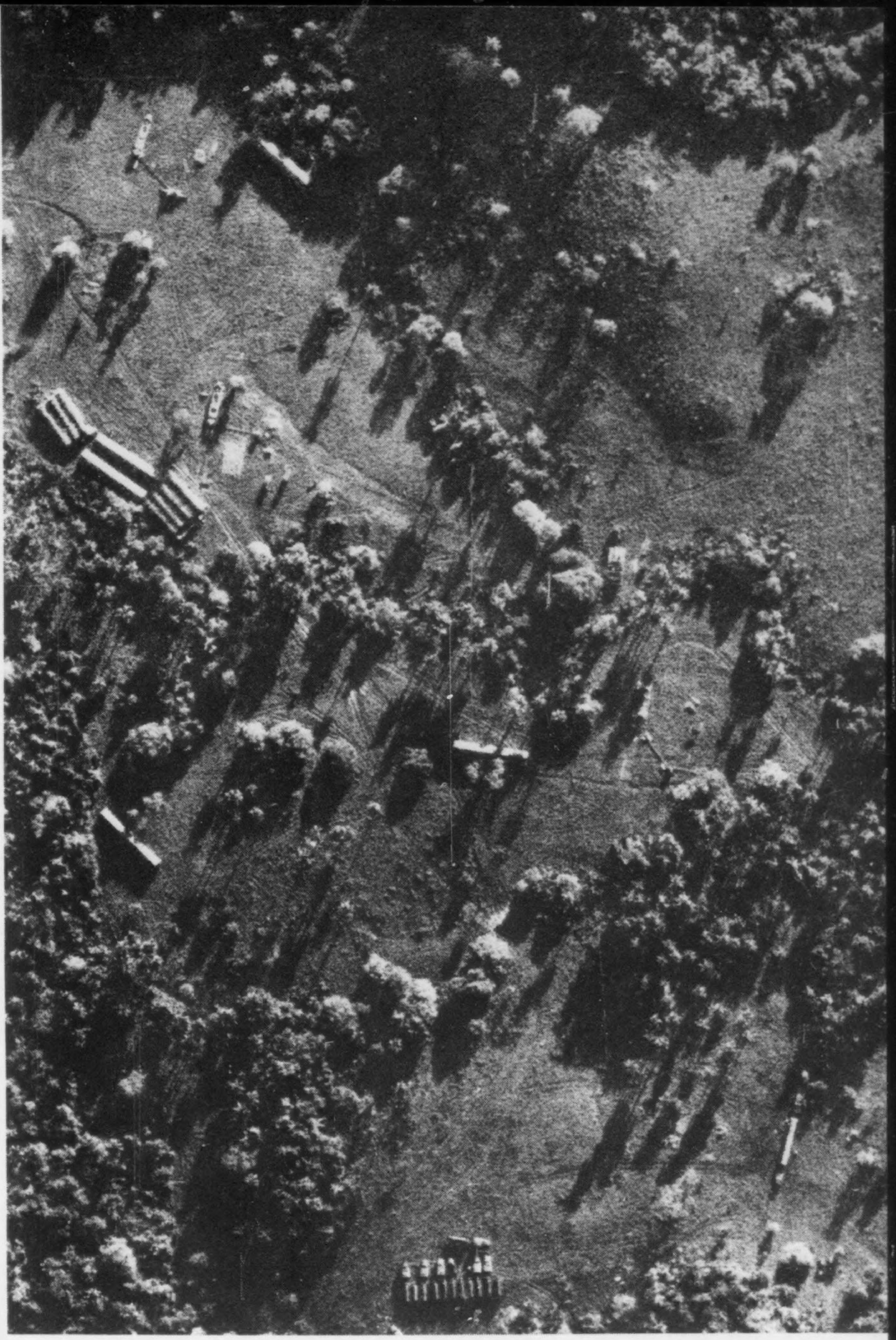
Dino A. Brugioni, a senior photo interpretation expert at the Central Intelligence Agency, has long advocated that schools, colleges, and universities train students to interpret aerial photos for historical content.

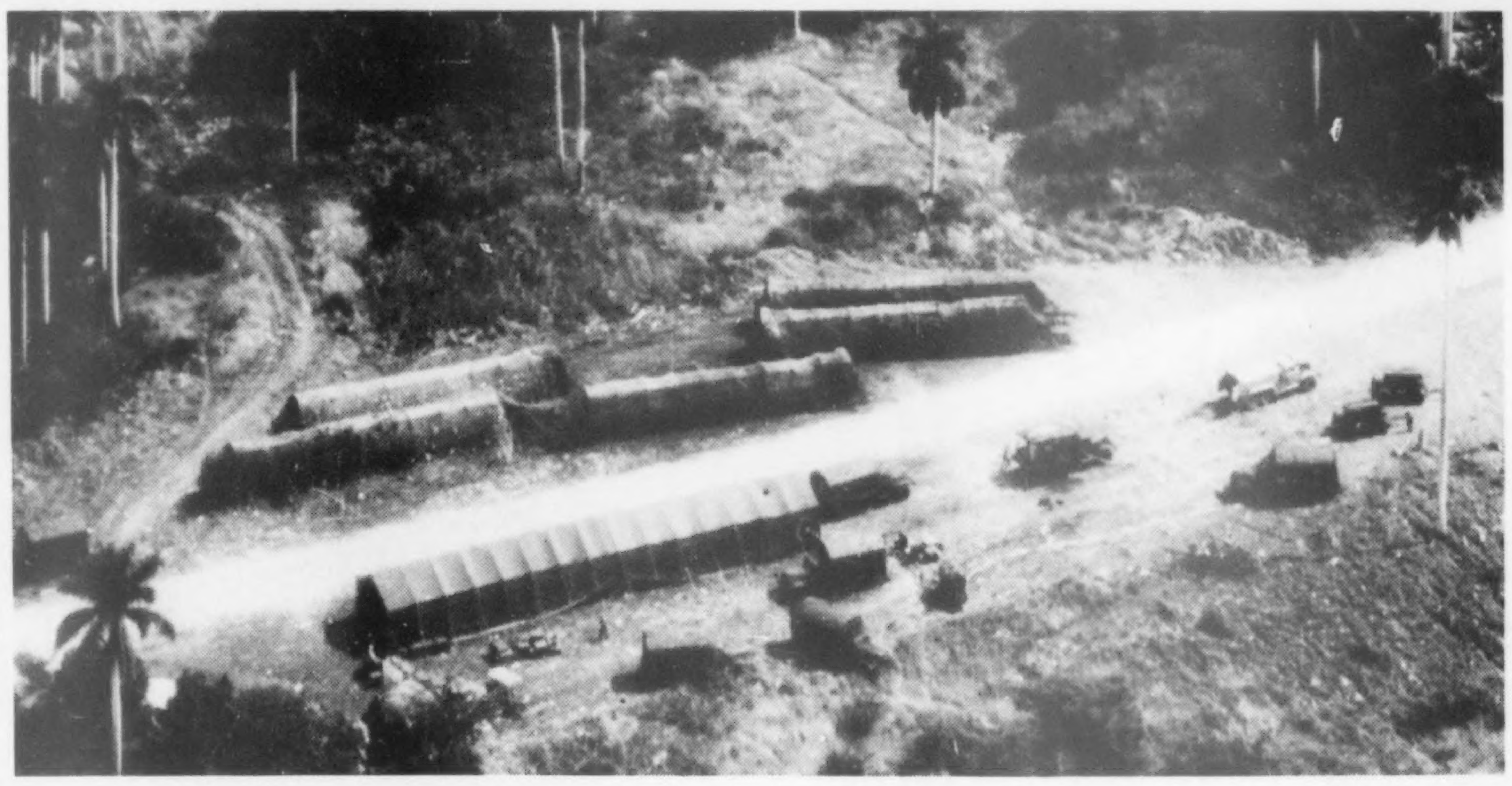
Mr. Brugioni has participated in the collection and analysis of hundreds of aerial photos of historic sites and events during the last 35 years. In public lectures, he challenges audiences to identify specific details contained in aerial photos, showing them photos of events or places that most people recognize immediately in ground-level photos but not from the unfamiliar perspective of the airborne camera.

On these pages are just a few of Mr. Brugioni's favorite aerial photographs of historically important places and/or events. How many can you identify? The correct interpretations are printed upside-down in the box on page 15.



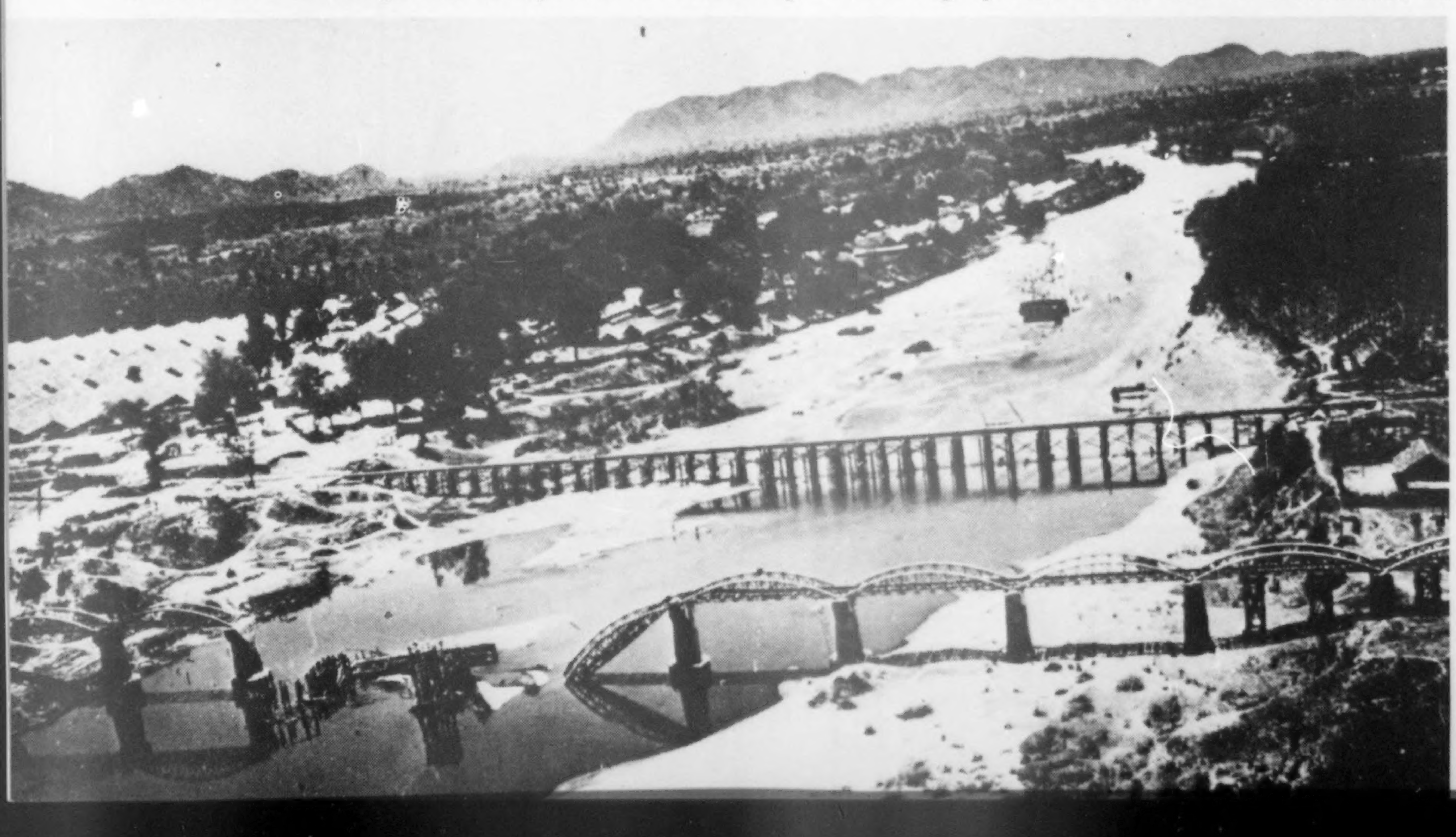
2 Certain shadows might give you a clue to this prime Hitler objective.





3 & 4 The objects in these photos presented President John F. Kennedy with a major crisis.

5 One of the bridges in this photo was built by "whistling" prisoners of war in World War II.



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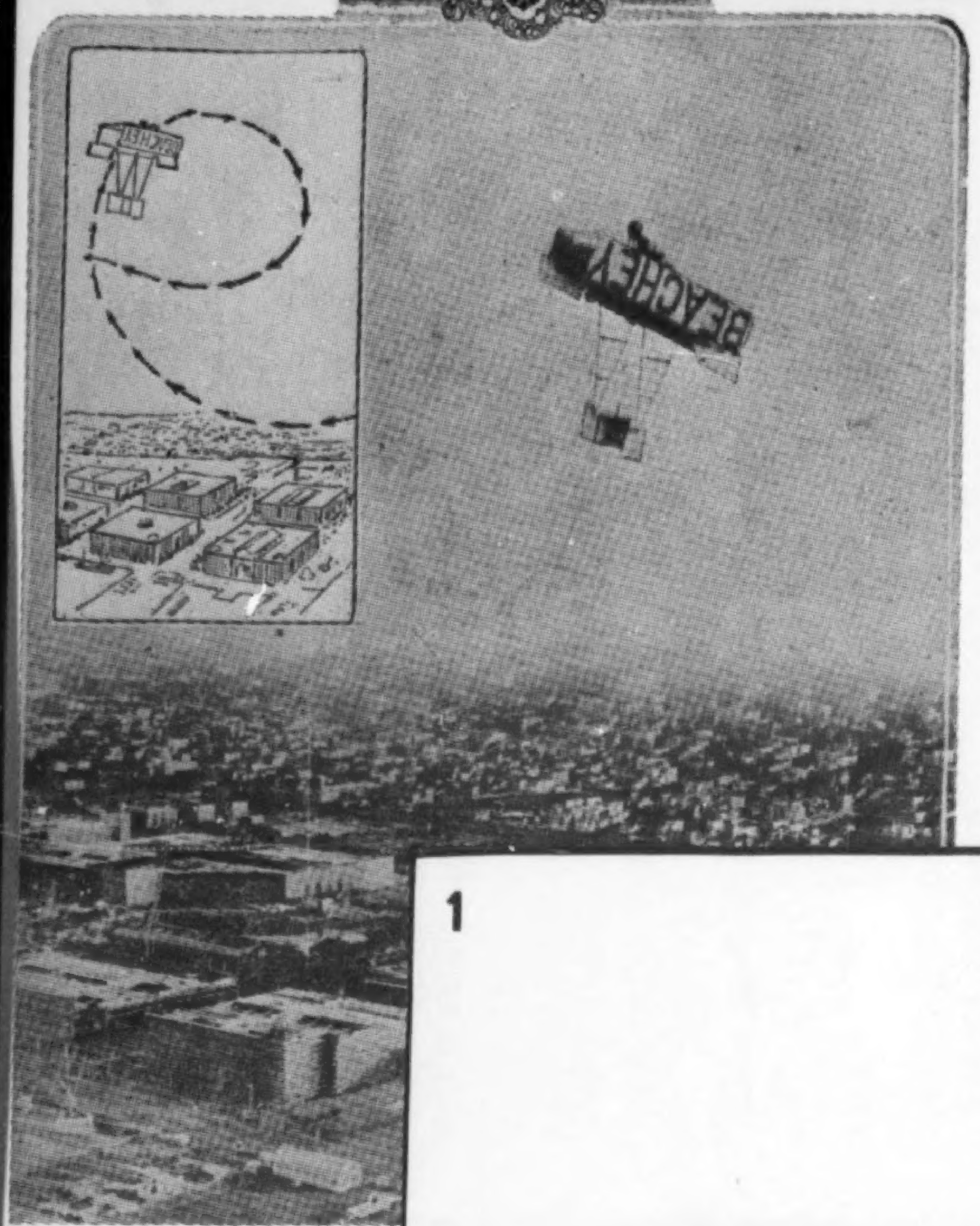
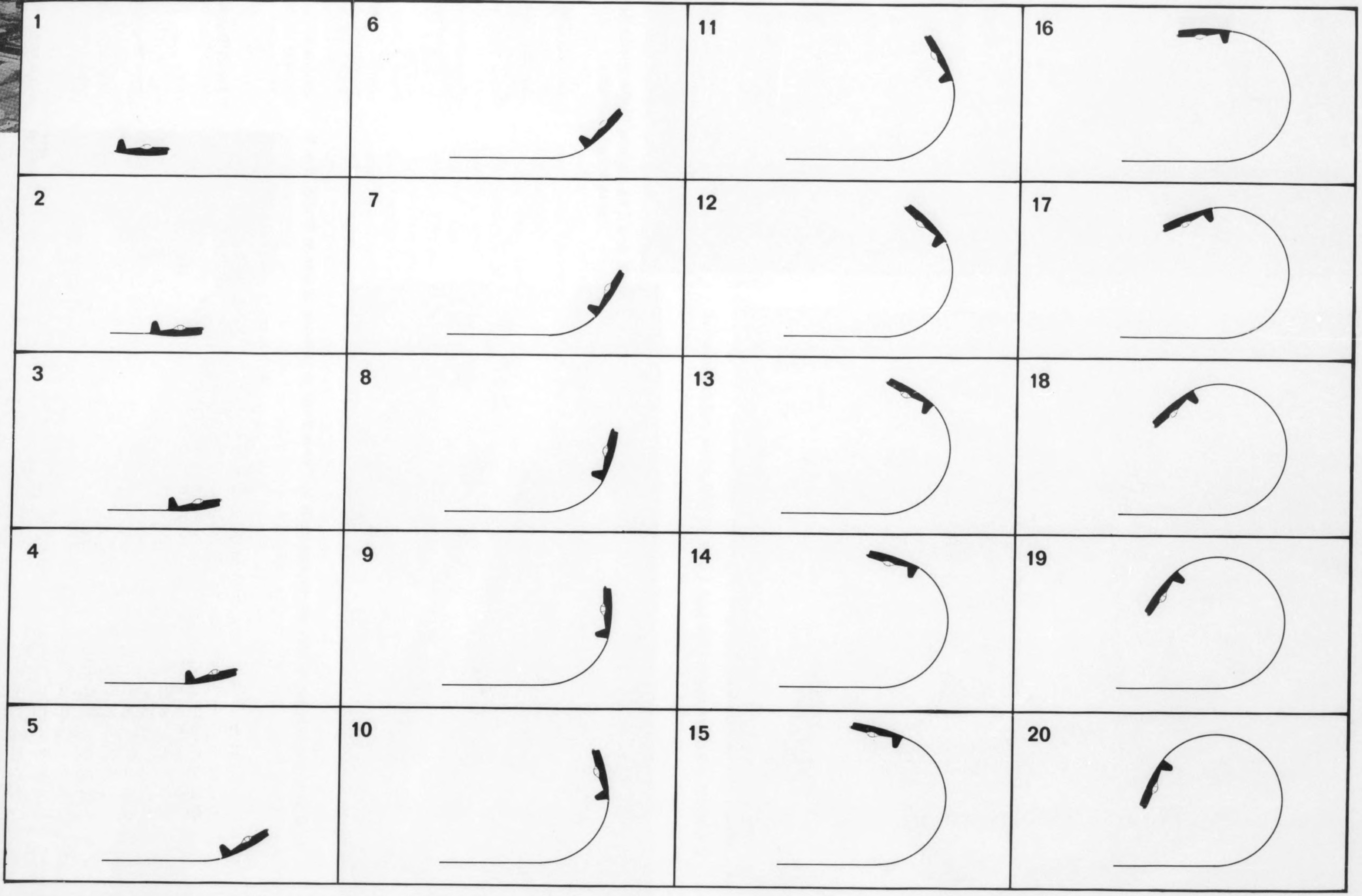


American exhibition pilot Lincoln Beachey (shown over San Francisco in his "Little Looper," Jan. 3, 1914, left) performed "death dives" and loops that earned him a reputation for utter fearlessness—and as much as $4,000 per week. Beachey was killed March 14, 1915, when he overstressed the wings of a new monoplane (right).

Fly a Perfect Loop!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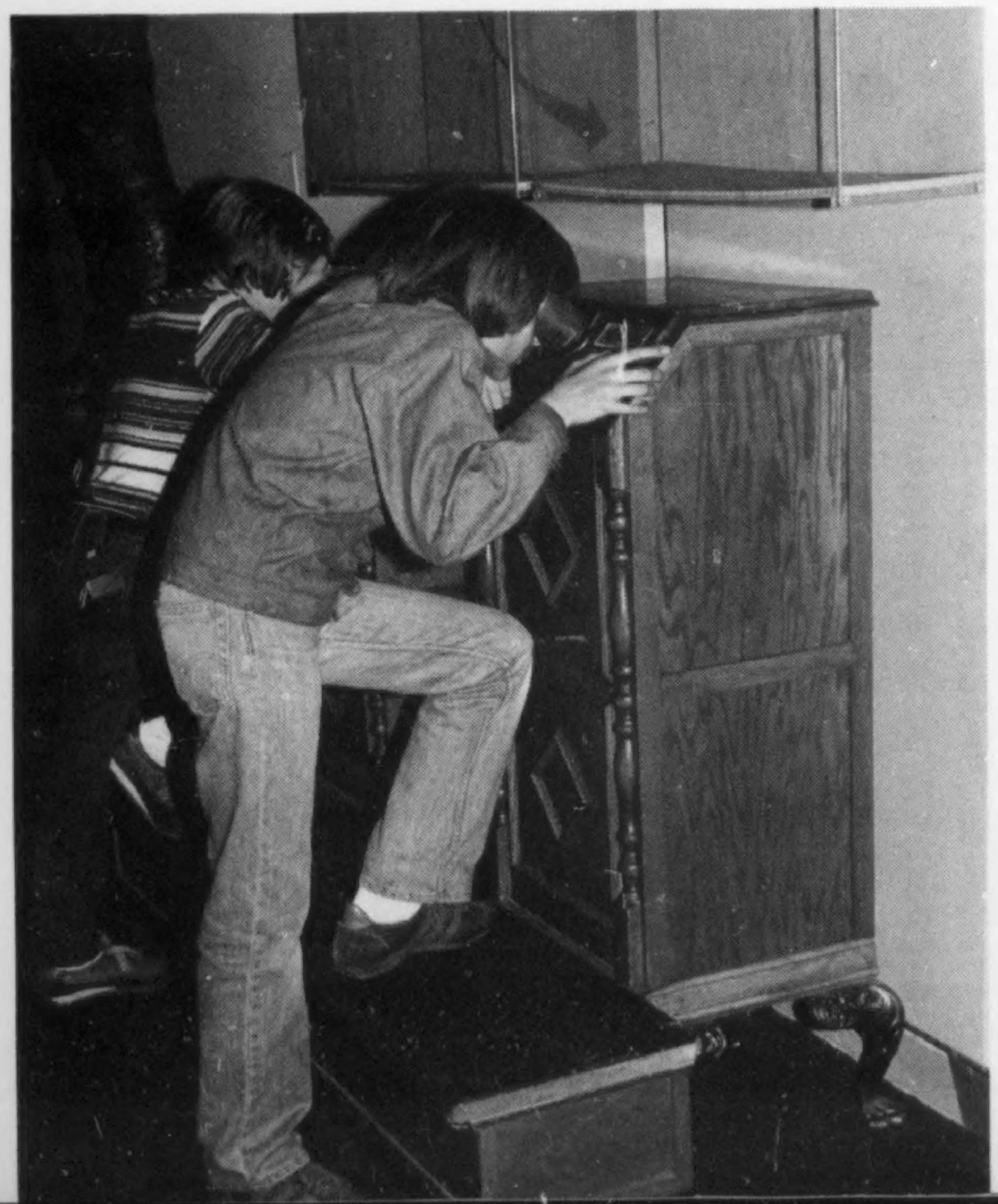
The loop is one of the basic four aerobatic maneuvers (loop, roll, spin, and hammerhead or stall turn), and was one of the first aerobatic maneuvers successfully completed. Aerobatic pilots often use the loop in combination with other maneuvers to create complex three-dimensional patterns in the sky.

Flying a basic loop is easy. Flying a *perfect* loop, on the other hand, is nearly impossible. Most loops flown by beginners, or in less powerful airplanes, come out egg-shaped. The airplane flies through the beginning and the end of the loop at higher speed, so the bottom is rounder and larger. But by the time the airplane reaches the top of the loop, gravity and the high drag of maneuvering have slowed it considerably, so it loops more tightly at the top.

If the pilot keeps the airplane from drifting right or left during the loop, the airplane will tremble slightly at the bottom of the loop as it flies through the turbulence created by its propeller at the start of the loop.

Make this flip book—and "fly" a perfect loop, "flight" after "flight."



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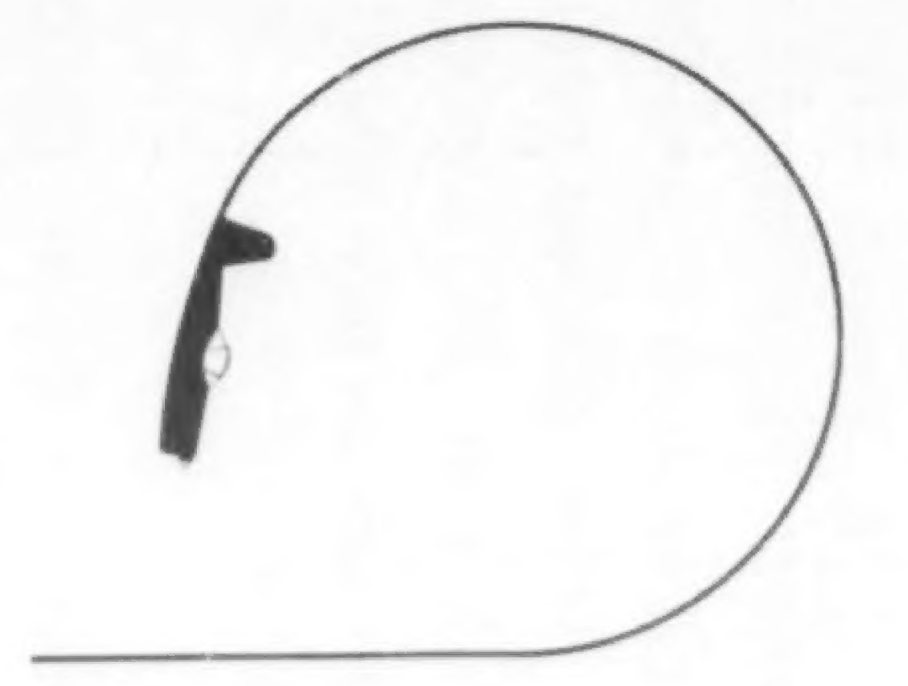

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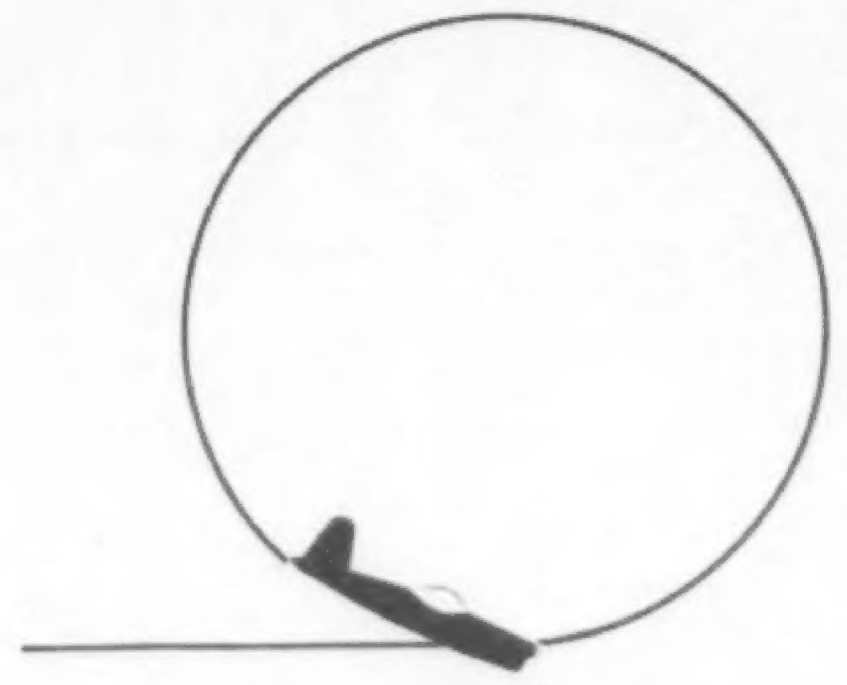

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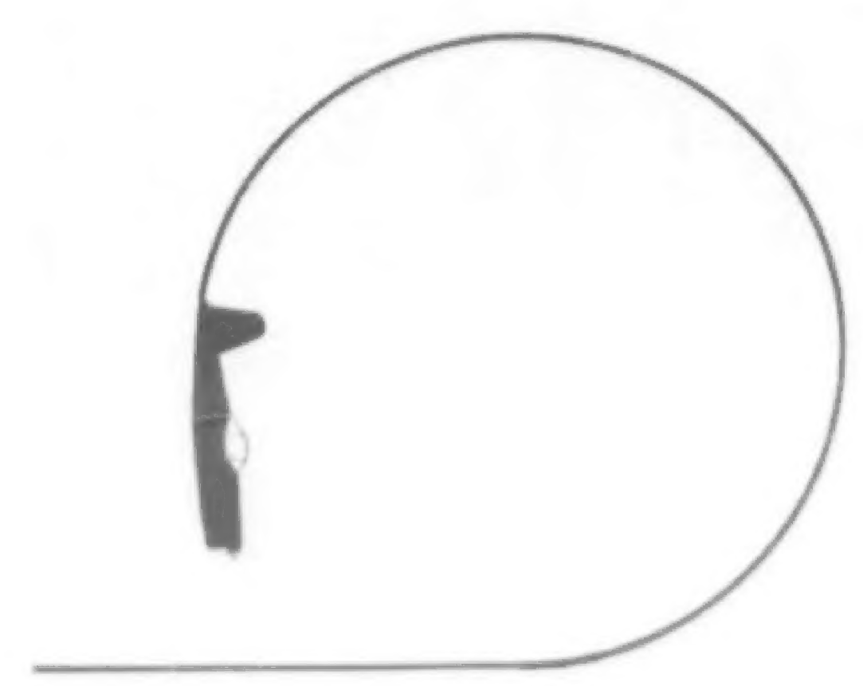

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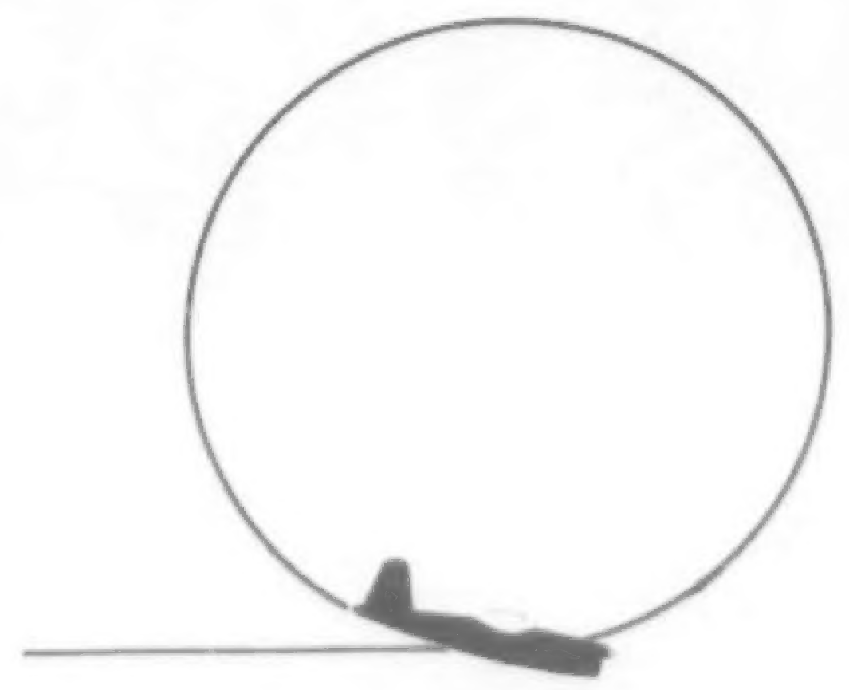

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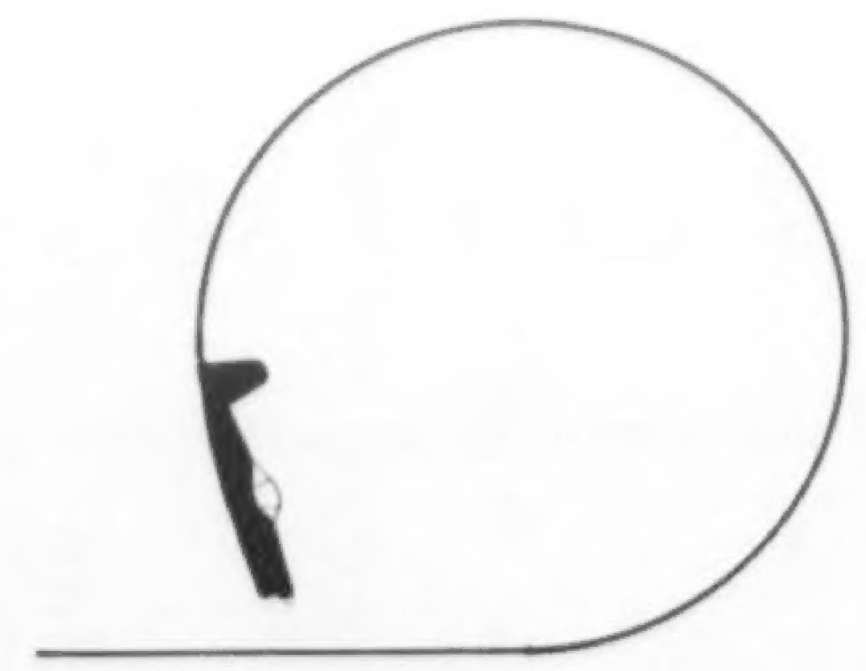

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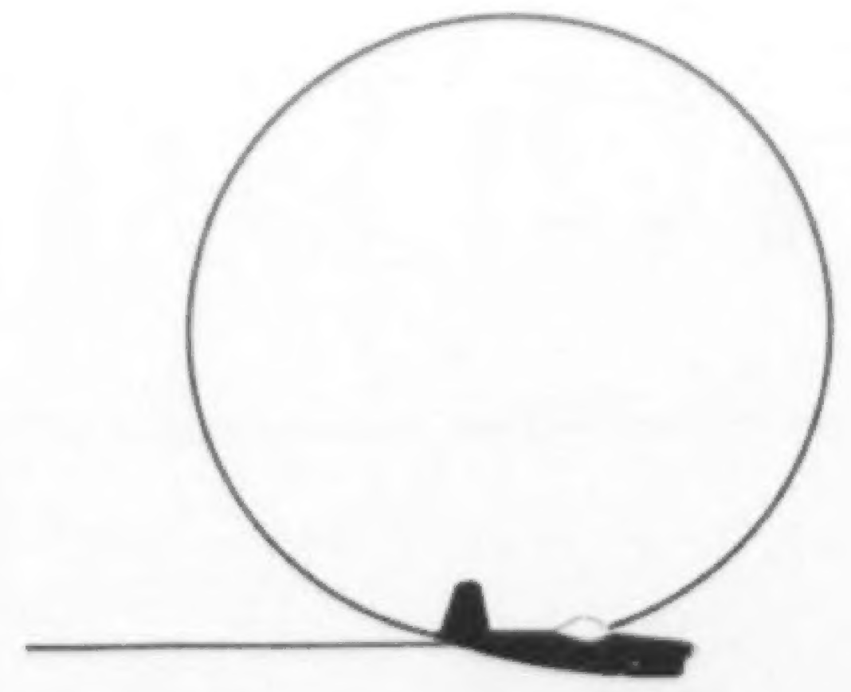

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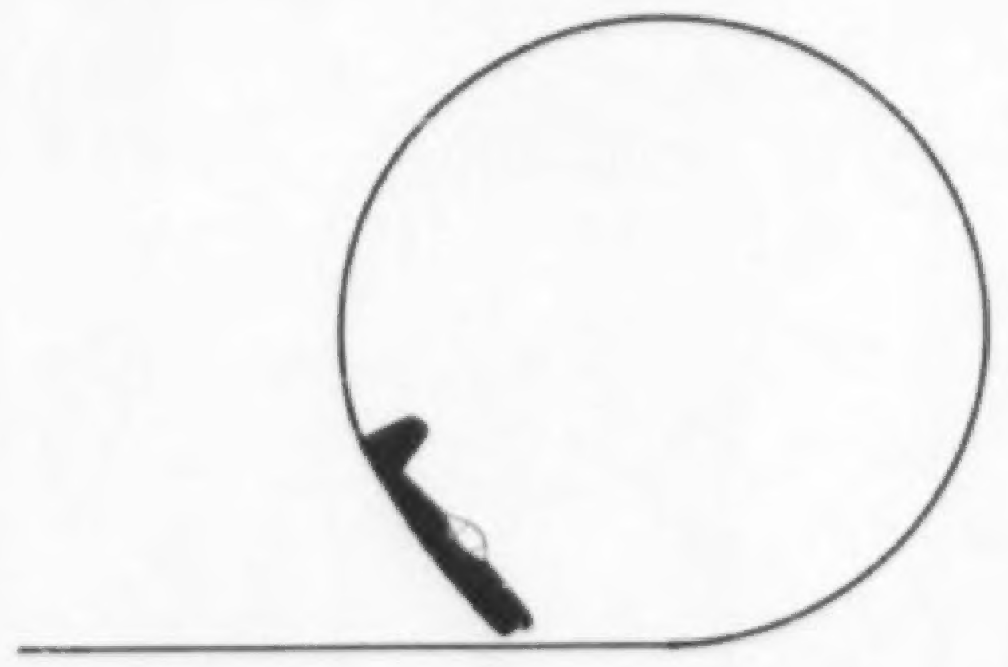

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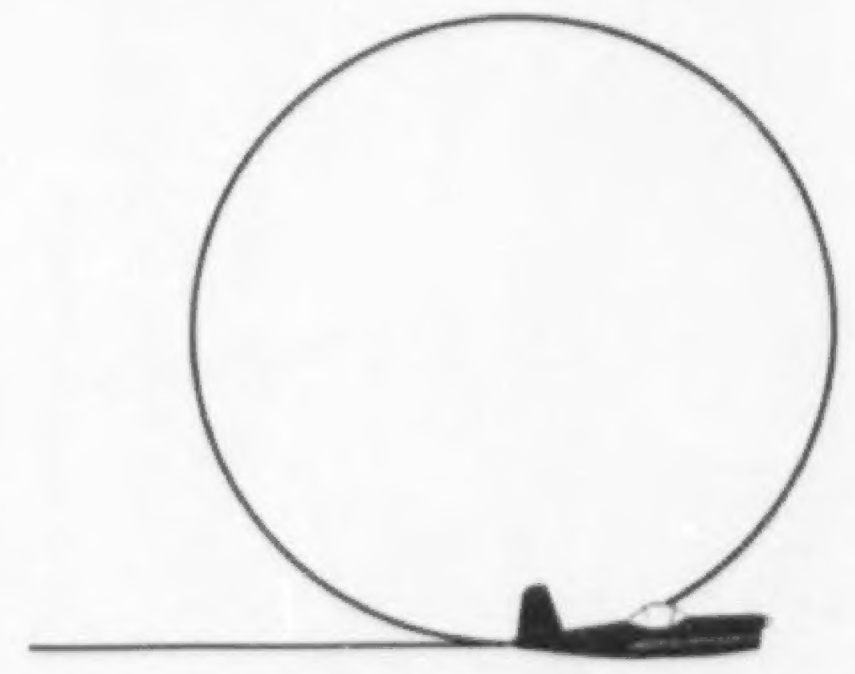

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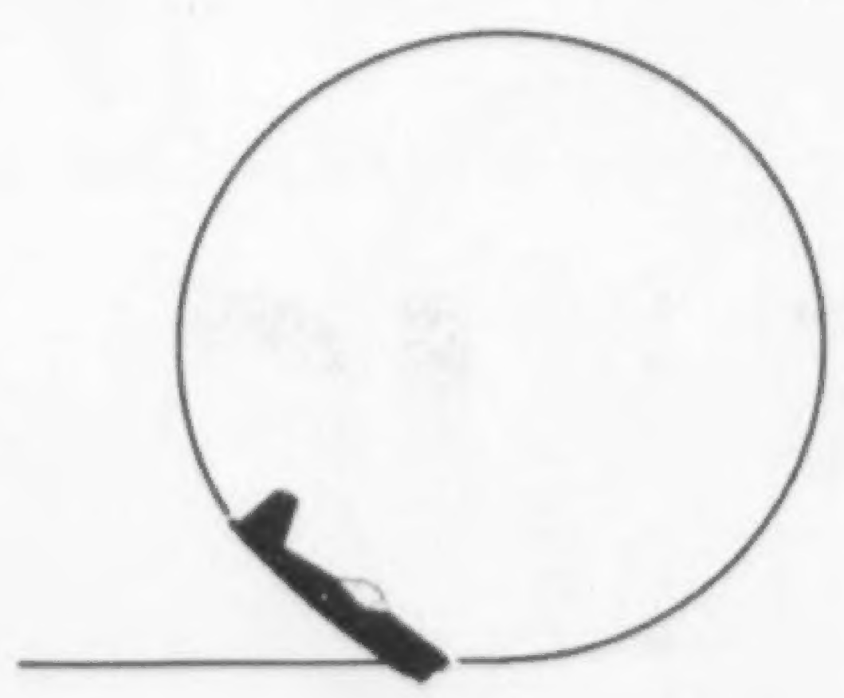

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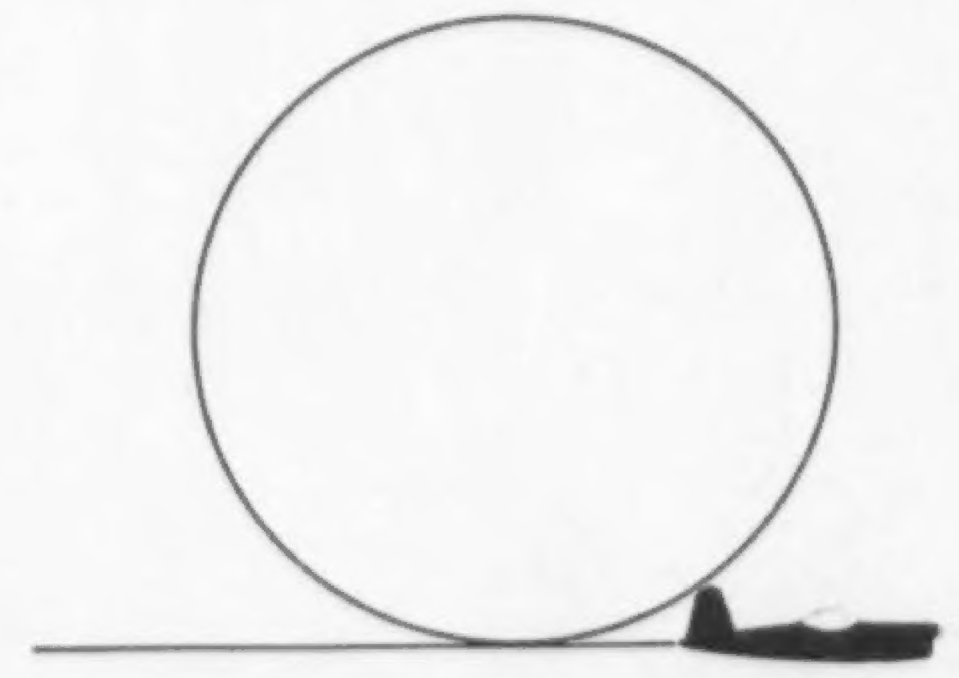


On your next visit to the National Air and Space Museum, see the mutascopes in the World War I gallery and the Social Impact of Flight gallery. These machines, popular early in the twentieth century, animate photographs like the flip book to illustrate aircraft maneuvers.

Student Activity

1. Make two copies of these pages by tracing, duplicating, or photocopying. (Two copies make a much smoother animation.)

2. Carefully cut the numbered pictures apart along the solid lines.

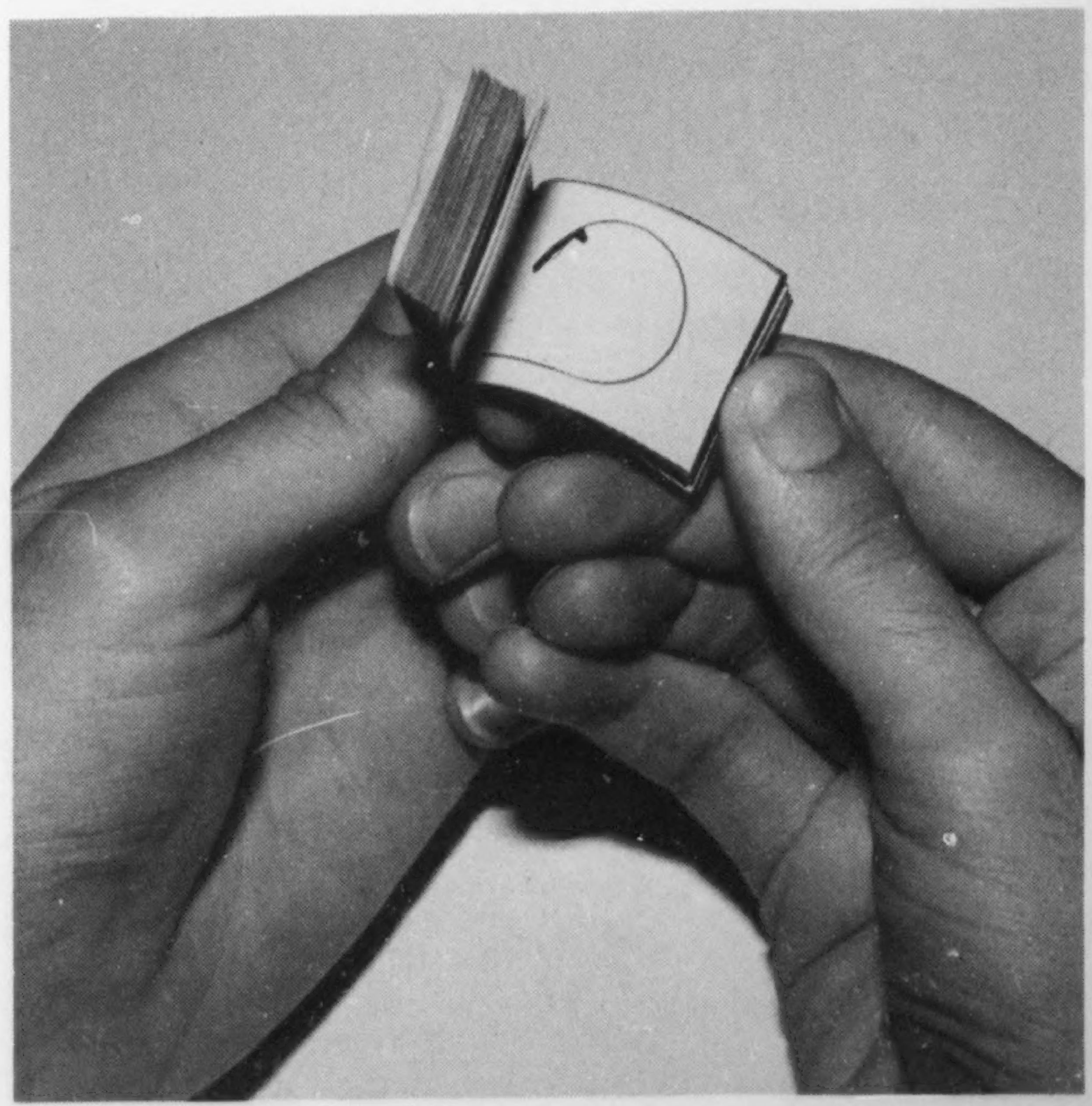
3. Stack the pictures in sequential order, with the two copies of Picture 1 on top, the two copies of Picture 2 next, and so forth.

4. Tap the right edge of the stack of pictures on a hard flat surface to align them. Be sure that the right edge of the stack is as even as possible.

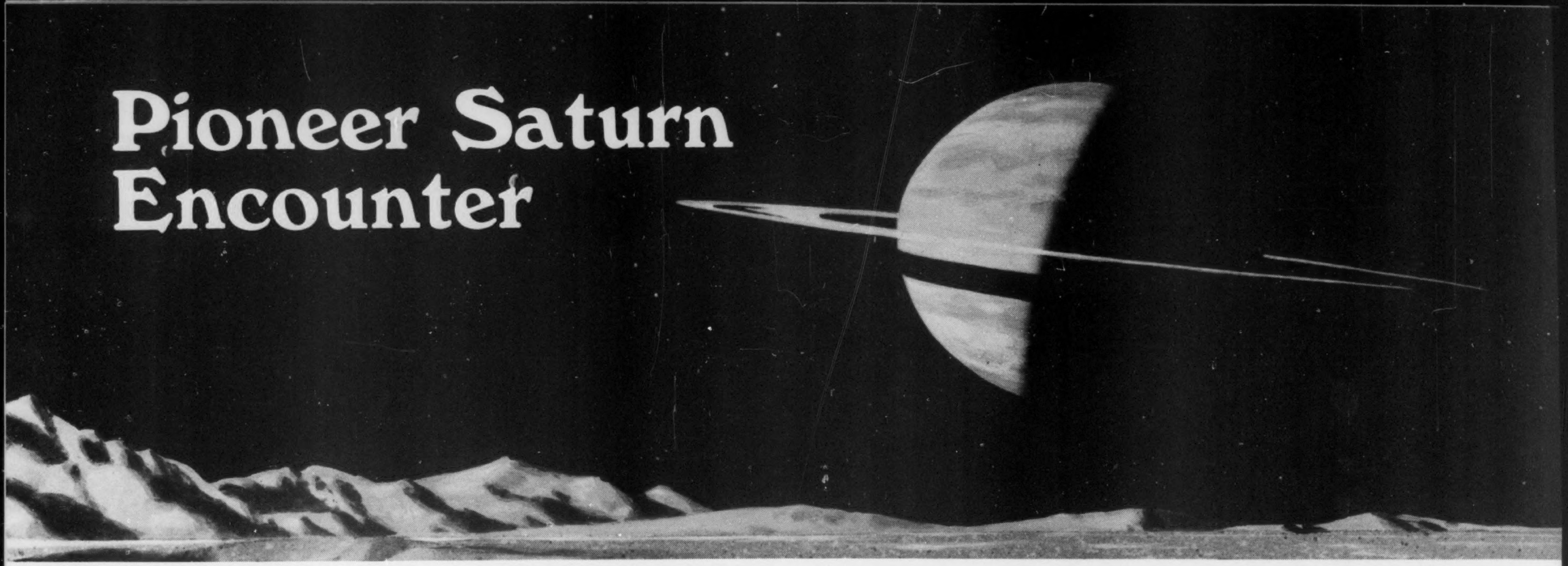
5. Staple the stack on the left margin. Try to keep the stack from shifting while stapling.

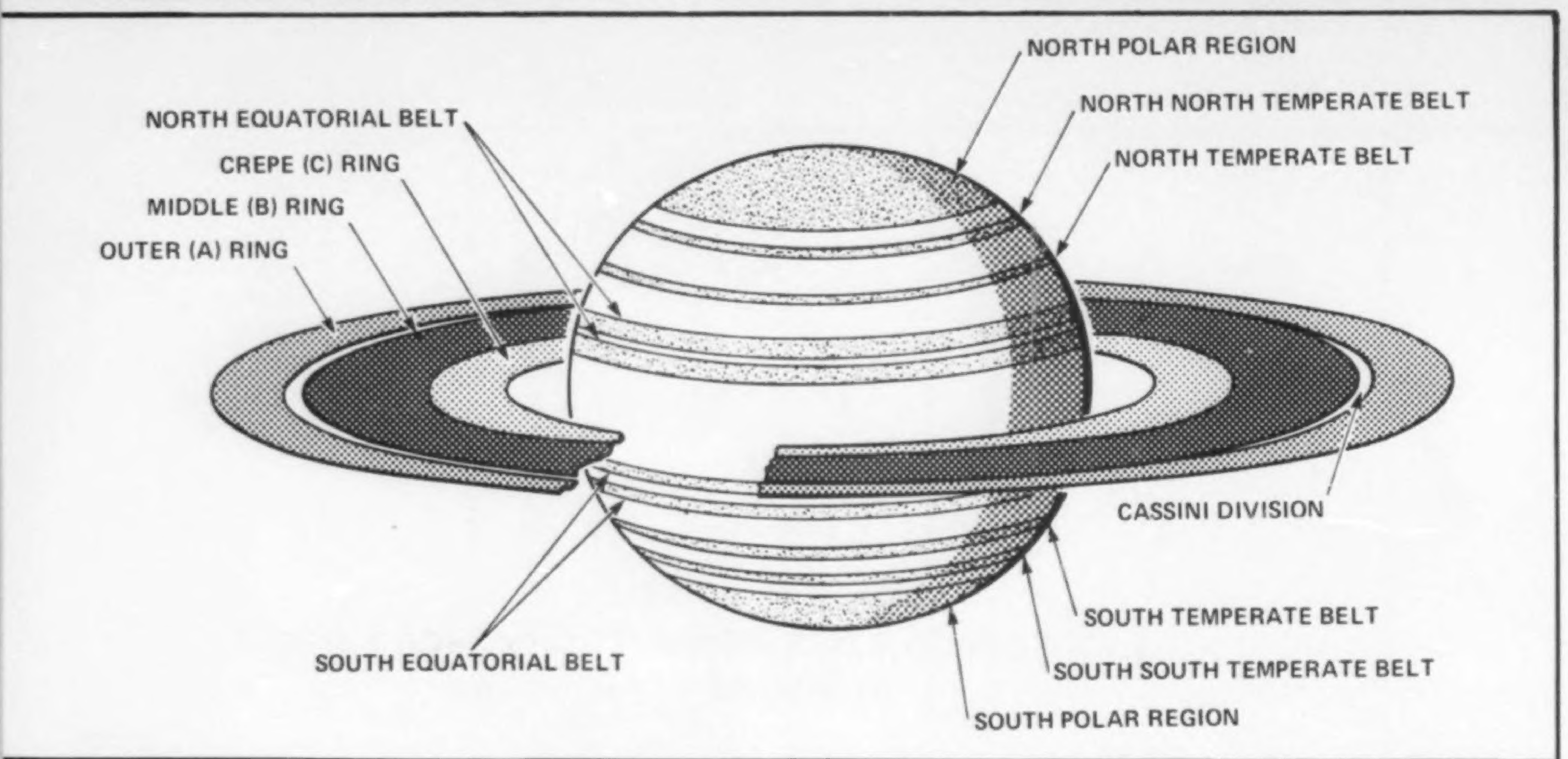
6. Hold the left side of the flip book in one hand. Flip the pages between the thumb and finger index of your other hand to see how an airplane performs a loop.

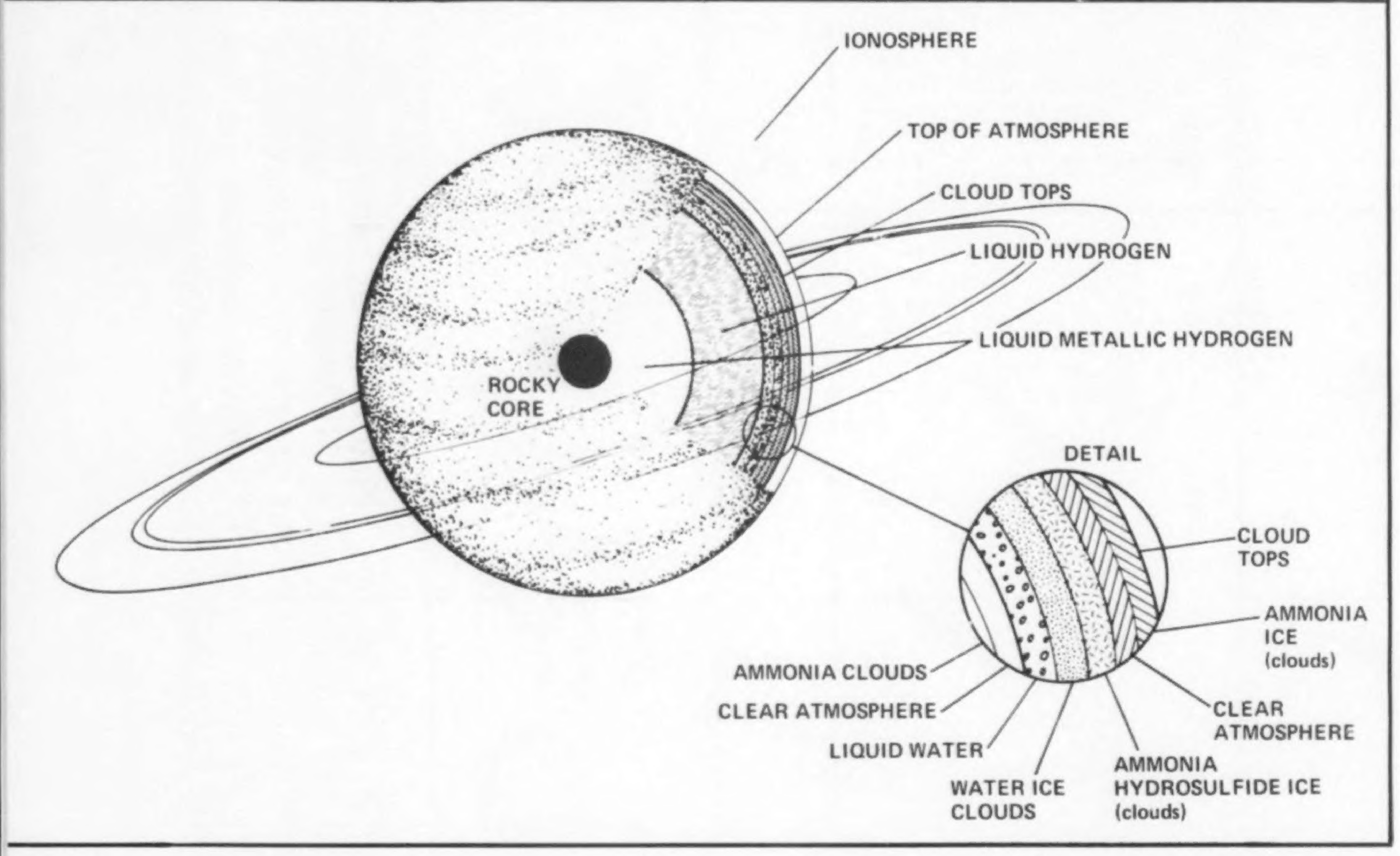
7. Look up other aerobatic maneuvers in the books listed elsewhere in this issue. Make your own flip book to show such maneuvers as the vertical roll, hammerhead turn, half roll, Immelmann turn, and chandelle.



Pioneer Saturn Encounter




NORTH POLAR REGION
NORTH NORTH TEMPERATE BELT
NORTH TEMPERATE BELT
NORTH EQUATORIAL BELT
CREPE (C) RING
MIDDLE (B) RING
OUTER (A) RING
CASSINI DIVISION
SOUTH TEMPERATE BELT
SOUTH SOUTH TEMPERATE BELT
SOUTH POLAR REGION
SOUTH EQUATORIAL BELT


IONOSPHERE
TOP OF ATMOSPHERE
CLOUD TOPS
LIQUID HYDROGEN
LIQUID METALLIC HYDROGEN
ROCKY CORE
DETAIL
CLOUD TOPS
AMMONIA ICE (clouds)
AMMONIA CLOUDS
CLEAR ATMOSPHERE
LIQUID WATER
CLEAR ATMOSPHERE
WATER ICE CLOUDS
AMMONIA HYDROSULFIDE ICE (clouds)

Above, space artist Ron Miller's conception of Saturn as seen from Rhea, one of its moons. Top left, scientists' model of Saturn's atmosphere; lower left, Saturn's belts and rings known prior to Pioneer 11's flyby.

Pioneer 11—renamed Pioneer Saturn—zoomed near Saturn in early September 1979 to give scientists their first close look at this giant, gaseous, ringed planet. The images taken by an instrument on board the 260-kilogram (570-pound) spacecraft defined features of Saturn better than any images taken from Earth. Photographs of the familiar rings, Saturn's cloud belts, and a view of Titan, the largest of Saturn's 10 moons, are being closely examined by scientists.

Pioneer 11's instruments have identified a strong magnetic field, a benign radiation environment, and a new gap in the planet's rings (tentatively called the Pioneer Gap). Scientists have also found evidence of a new ring beyond the outer edge of the four known rings (the A, B, C, and D Rings). This new feature is being called the F Ring for the time being.

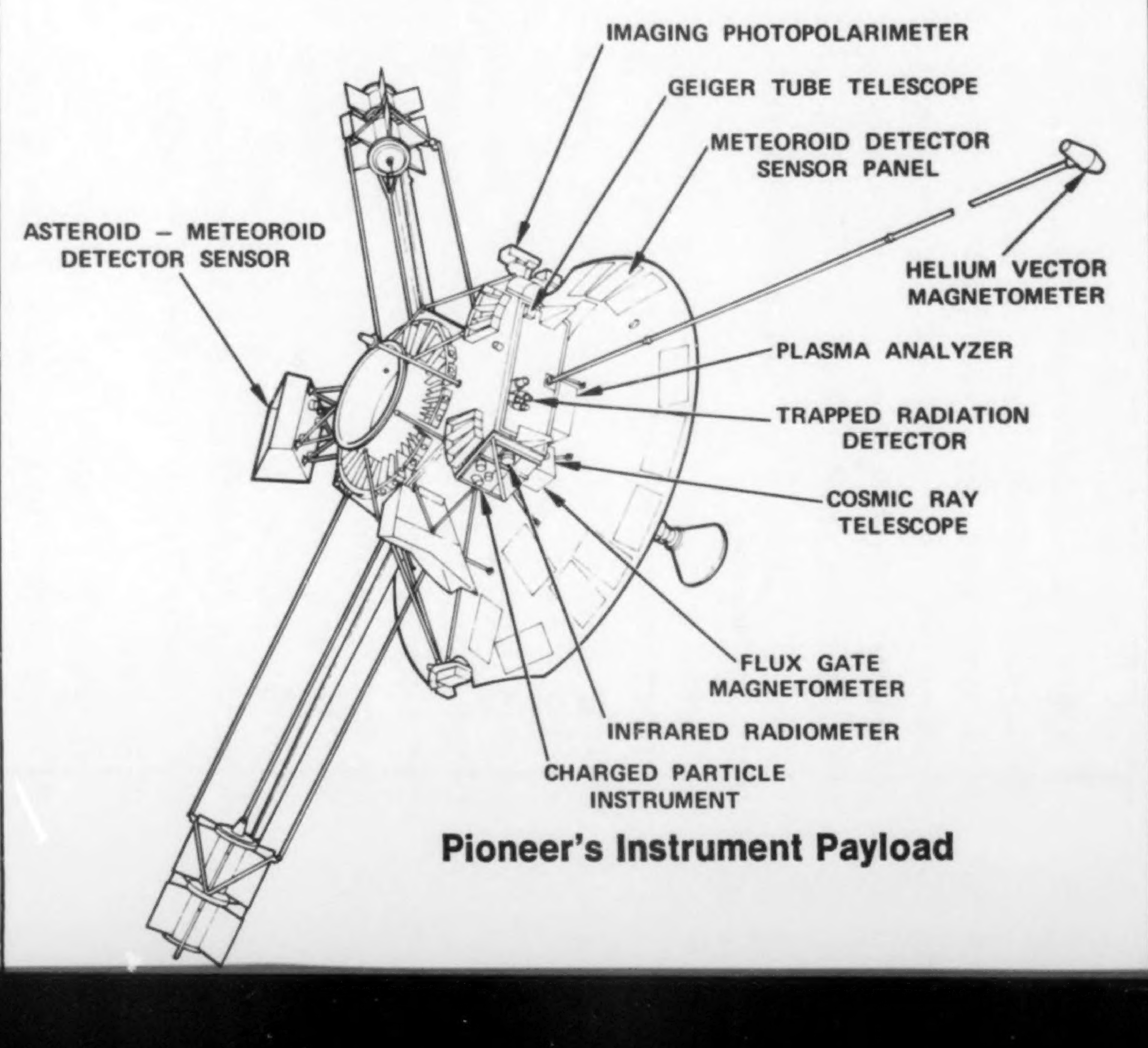
Traveling for 6½ years across more than 3 billion kilometers (2 billion miles) of space, Pioneer 11 was the first spacecraft to reach Saturn. This extraordinary accomplishment blazed a trail for the Voyager 1 and 2 spacecraft targeted for Saturn fly-bys in 1980 and 1981. The Voyager spacecraft are more sophisticated than the Pioneers, and scientists expect the Voyagers to provide greatly superior data on Saturn. But the success of Pioneer 11 was critical in plotting the best possible path for the Voyagers' Saturn encounters.

Pioneer 11 approached Saturn along a trajectory that brought the spacecraft above the planet. From this position the rings of Saturn were between the spacecraft and the Sun, permitting optical measurements of the ring structure never before possible. Earth-based observations of the rings provide only a front-lighted view, and only through a very small range of angles.

Pioneer's path continued in a perilous flight through the plane of the rings to within 20,200 kilometers (12,560 miles) of Saturn's cloud tops. The spacecraft disappeared behind the planet to emerge beneath the sunlit side of the rings after 78 minutes of radio silence.

Pioneer 11 made a second ring plane crossing on its ascent from the planet. Eventually, Pioneer 11 will escape the solar system, traveling in a direction opposite to that of its sister spacecraft, Pioneer 10. Scientists expect to be able to communicate with Pioneer 10 and 11 through the mid-1980's. Both Pioneers carry a message plaque for any intelligent species that might intercept the spacecraft during their endless journeys through space.

Pioneer 11 was built by TRW Systems Group, and is managed by NASA Ames Research Center, Mountain View, California. A replica of the Pioneer spacecraft is on exhibit in the Milestones of Flight gallery at the National Air and Space Museum.


IMAGING PHOTOPOLARIMETER
GEIGER TUBE TELESCOPE
METEOROID DETECTOR SENSOR PANEL
ASTEROID – METEOROID DETECTOR SENSOR
HELIUM VECTOR MAGNETOMETER
PLASMA ANALYZER
TRAPPED RADIATION DETECTOR
COSMIC RAY TELESCOPE
FLUX GATE MAGNETOMETER
INFRARED RADIOMETER
CHARGED PARTICLE INSTRUMENT

Pioneer's Instrument Payload

Student Activity

1. Scientists often use very large or small numbers in measuring distances. Instead of writing a series of zeros to show place values, it is easier to write such a number as a numeral between 1 and 10 multiplied by the appropriate power of 10. This convention is called *scientific notation*. For example, Earth is 150,000,000 kilometers from the Sun; in scientific notation, this distance is expressed as 1.5×10^8 kilometers. Practice writing the numbers on the planetary chart using scientific notation.

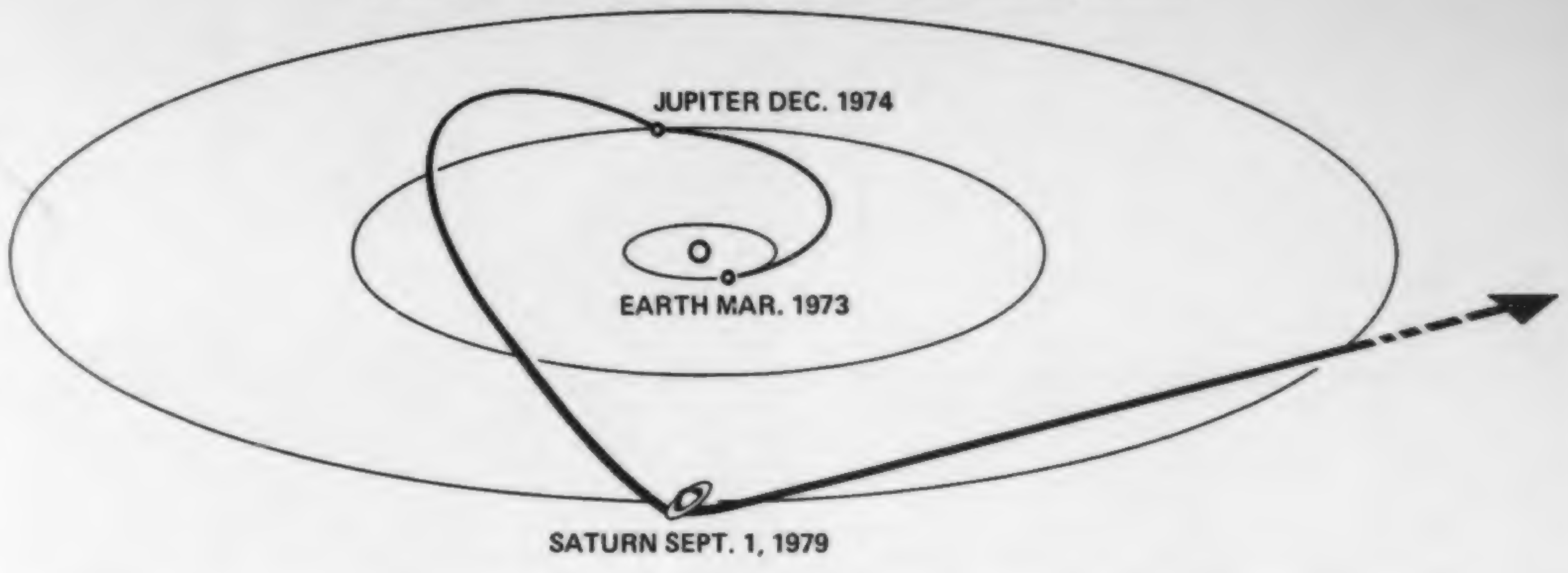
2. Other units that scientists use to represent large distances in space include *astronomical units* and *light years*.

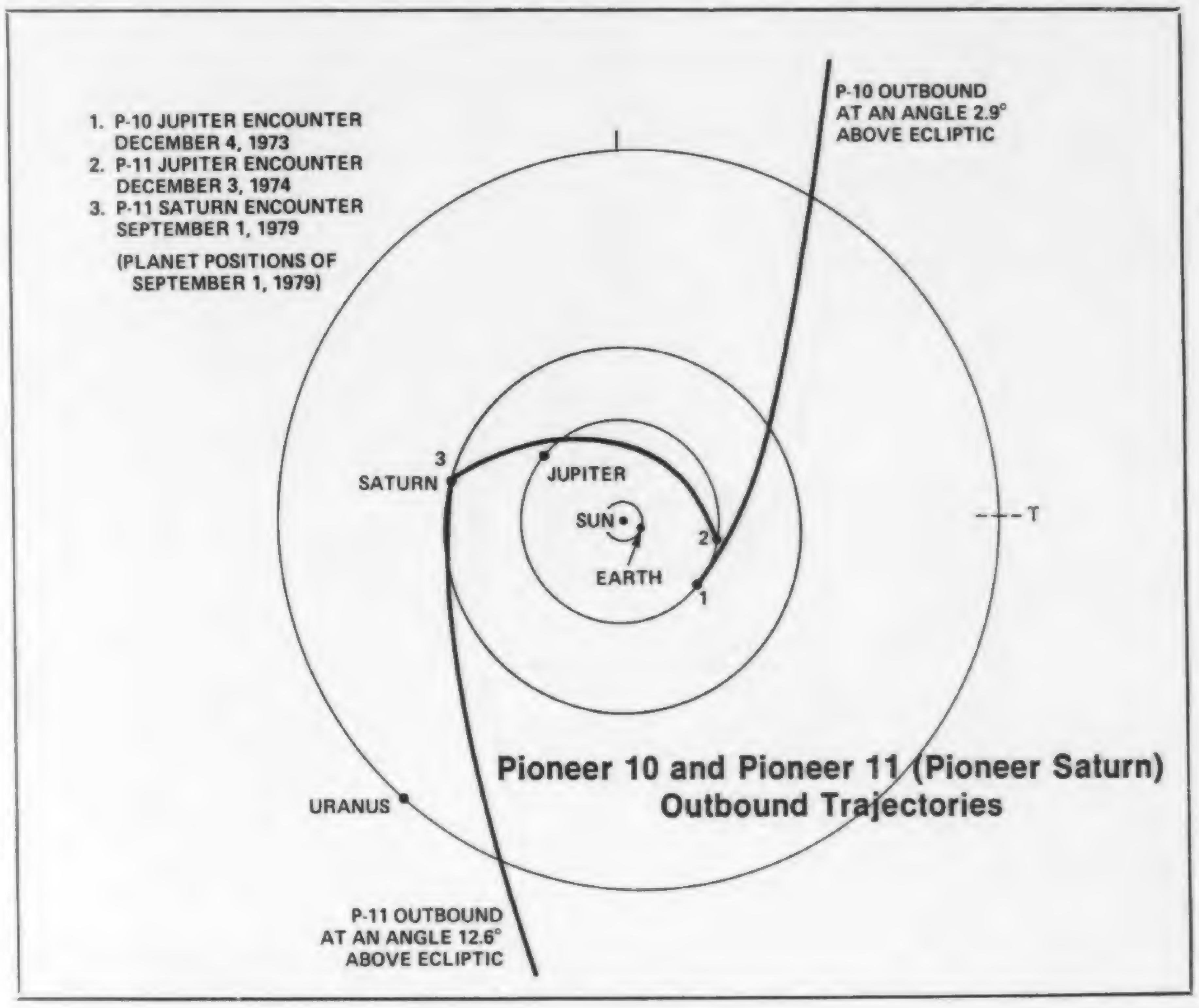
An astronomical unit (A.U.) is the average distance between Earth and the Sun (i.e., Earth is 1 A.U. from the Sun). How many kilometers (or miles) are there in 5 A.U.?

Distances between stars and galaxies—thousands and millions of A.U.'s—are much greater than distances between planets. Therefore scientists use another unit, the light year, which is the distance light travels in a vacuum in one year. If light travels at 2.99×10^8 meters (1.86×10^5 miles) per second, how many kilometers (or miles) are there in one light year?

3. Calculate the nearest and farthest distances between Earth and each of the other planets. Find the nearest and farthest possible distances between each of the planets. Make your own chart illustrating the data, or supplement the given chart.

Pioneer 11's Path Through the Solar System


JUPITER DEC. 1974
EARTH MAR. 1973
SATURN SEPT. 1, 1979


1. P-10 JUPITER ENCOUNTER DECEMBER 4, 1973
2. P-11 JUPITER ENCOUNTER DECEMBER 3, 1974
3. P-11 SATURN ENCOUNTER SEPTEMBER 1, 1979
(PLANET POSITIONS OF SEPTEMBER 1, 1979)
P-10 OUTBOUND AT AN ANGLE 2.9° ABOVE ECLIPTIC
SATURN
3
JUPITER
SUN
EARTH
2
1
T
URANUS
P-11 OUTBOUND AT AN ANGLE 12.6° ABOVE ECLIPTIC

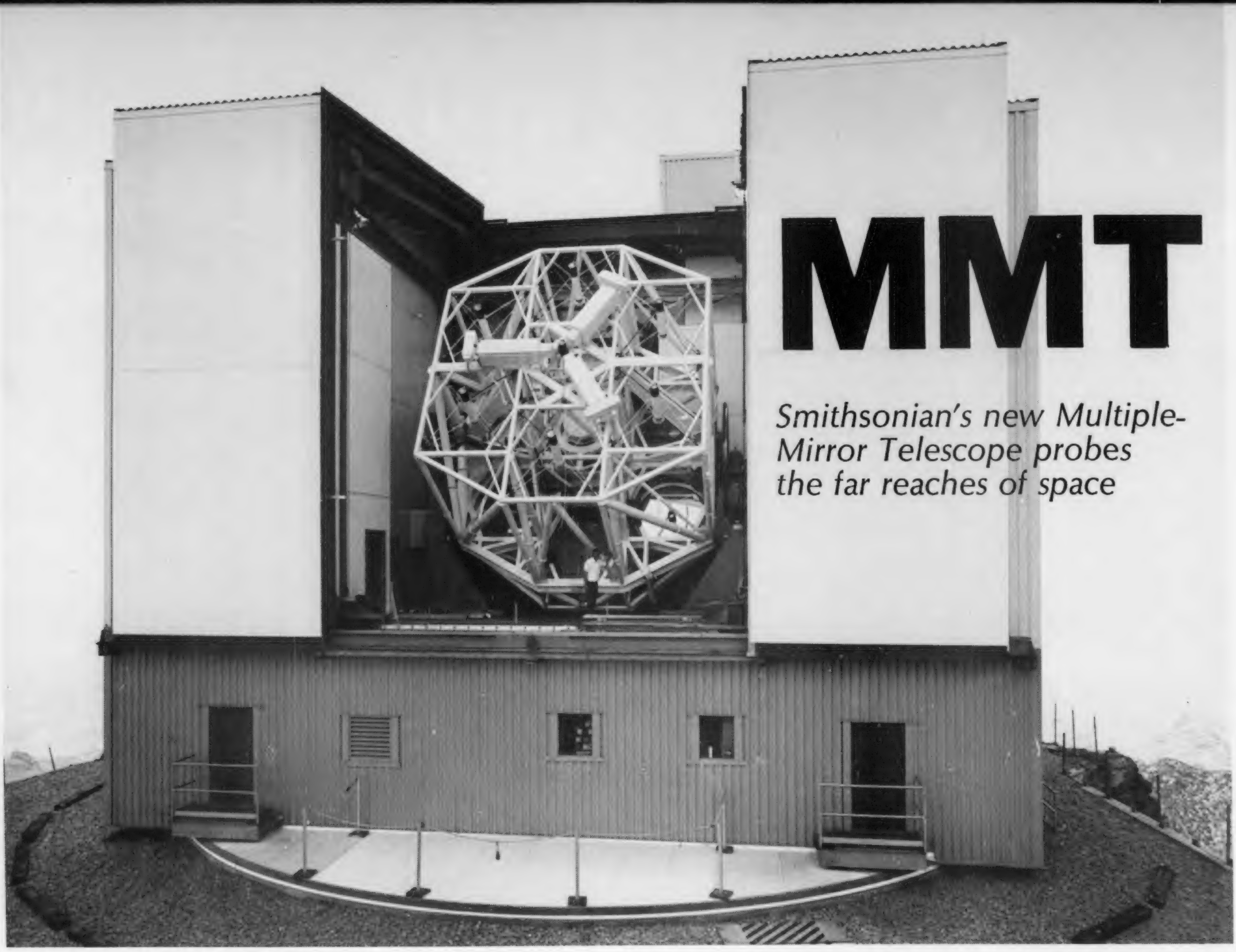
Pioneer 10 and Pioneer 11 (Pioneer Saturn) Outbound Trajectories

Solar System Statistics

Planet	Symbol	Average distance from the Sun			Equatorial diameter			Period of revolution, years	Period of rotation, days
		Million kilometers	Million miles	Astronomical units	Kilometers	Miles	Relation to Earth		
Mercury	☿	57.9	36.0	.387	4,880	3,032	.38	.24	58.60
Venus	♀	108.2	67.2	.723	12,100	7,519	.95	.62	243.00
Earth	⊕	149.6	93.0	1.00	12,756	7,927	1.00	1.00	1.00
Mars	♂	228.0	141.7	1.52	6,784	4,215	.53	1.88	1.03
Jupiter	♃	778.0	483.4	5.20	143,200	88,984	11.20	11.86	.41
Saturn	♄	1,425.0	885.5	9.52	120,000	74,568	9.41	29.46	.43
Uranus	⛢	2,867.0	1,781.6	19.20	51,800	32,189	4.10	84.01	.67
Neptune	♆	4,486.0	2,787.6	30.00	49,500	30,759	3.90	164.10	.77
Pluto	♇	5,890.0	3,660.0	39.4	2,600	1,616	.20	247.00	.39

MMT

Smithsonian's new Multiple-Mirror Telescope probes the far reaches of space



by T. H. Callen II
Production Specialist
Albert Einstein Spacearium, NASM

On May 9 the Smithsonian Institution and the University of Arizona jointly dedicated a six-eyed, far-seeing mechanical marvel perched high atop Mt. Hopkins in Arizona's Santa Rita Range. This unusual creation, the Multiple Mirror Telescope or MMT, may look like a bug-eyed, pipe fitter's nightmare, but it's really the working prototype for a whole new generation of astronomical telescopes.

The MMT was created to solve a fundamental problem that has confronted optical astronomers for years: To see farther into the universe, the light-gathering part of the telescope (the primary lens or mirror) must have more surface area. But more collection surface means more glass, and that means more weight. The problem could not be solved simply by scaling up existing telescope designs. When the primary lenses or mirrors and their supports are made too large, they begin to deform, and eventually collapse under their own weight.

The MMT, taking advantage of sophisticated computer technology, embodies a new approach to the problem. The designers of the MMT used several smaller mirrors with a lighter support structure, gathering the light at one focus.

The idea of using multiple detectors feeding data to one point is not new. This principle, known as interferometry, has been used in radio astronomy with great success by receivers separated over great distances. Multiple-mirror designs had been tried before, but none of the earlier models could maintain a stable image once the light from all the mirrors was brought to a common focus. With advances in computer and laser technologies, the problem was solved.

There are two basic types of telescopes: In *refracting* telescopes, light enters the telescope tube and is bent, or refracted, to the eyepiece by a lens. The largest refractor, at the Yerkes Observatory, Williams Bay, Wisconsin, has a collecting lens 102 centimeters (40 inches) in diameter.

In *reflecting* telescopes, light travels down the length of the telescope to a large, specially curved mirror. This mirror gathers and reflects the light back up the tube to a smaller, secondary mirror which reflects the light to the focus. The largest reflecting telescope in use is the 6.0-meter (236-inch) Russian telescope at the Crimean Astrophysical Observatory; according to some astronomers, it has continued to be troubled by cracks and bubbles in its massive mirror. The second largest reflector is the Hale 5.08-meter (200-inch) telescope at Mount Palomar in California.

The MMT, also a reflecting telescope, is currently the third largest telescope in the world, with an equivalent diameter of 4.5 meters (176 inches)—i.e., the six 1.8-meter (72-inch) mirrors of the MMT have the same light-gathering power as a single 4.5-meter (176-inch) mirror. Bringing this light together is a magnificent breakthrough in telescope construction.

To keep the six beams of light converging on the same point, the MMT uses a so-called "active optics" system. The six individual telescopes gather light from celestial objects and reflect it to the smaller secondary mirrors, just like conventional reflecting telescopes. Here the similarities end.

A weak laser beam is introduced into each telescope, where it follows a light path similar to starlight. The laser beam travels through the entire optical system of the MMT until it is intercepted by electronic sensors at the back of the telescope. These electronic sensors, working in conjunction with a small on-line computer, adjust the secondary mirrors so that the six artificial stars generated by the laser beam are superimposed. A third or tertiary mirror then reflects the light from the now correctly-aligned secondary mirrors into the center of the six-mirror array. Here it is once again re-directed to a focal point where it can be analyzed by electronic instruments. Since the laser beams and starlight reflect from the same mirrors, the starlight is in focus when the light from the laser "stars" is focused.

The MMT is less subject to structural problems than conventional reflectors. Its optical arrangement is so compact that all of the mirrors and their associated electronics can be supported by a simple altitude-azimuth mount, instead of the cumbersome and complicated equatorial mount.

Altitude-azimuth mounts have not been used for large telescopes in the past because of positioning problems in following the apparent motion of celestial objects across the sky as the earth rotates. The horizontal and vertical axes of rotation for this type of mount make precise alignment very difficult because of the need for constant and varying adjustment of the two axes. Once again, computers come to the rescue, helping to keep the altitude-azimuth mount pointed precisely where the astronomers want it.

In traditional observatories, the dome protecting the telescope from weather turns with the telescope to provide a clear line of sight through the dome's observation slit. Because the MMT uses an altitude-azimuth mount, at least half of the observatory would have to turn in the azimuth direction as well. The MMT's designers decided that its roof could be extended to the ground and made to rotate. The entire 4½-story, 454,000-kilogram (500-ton) building—including workshops, labs, offices, and lunchrooms—slowly rotates on steel wheels riding on a steel track like an overgrown battleship turret gun. Instead of the traditional dome shape, the observatory building is a cube, which increases the usable work space.

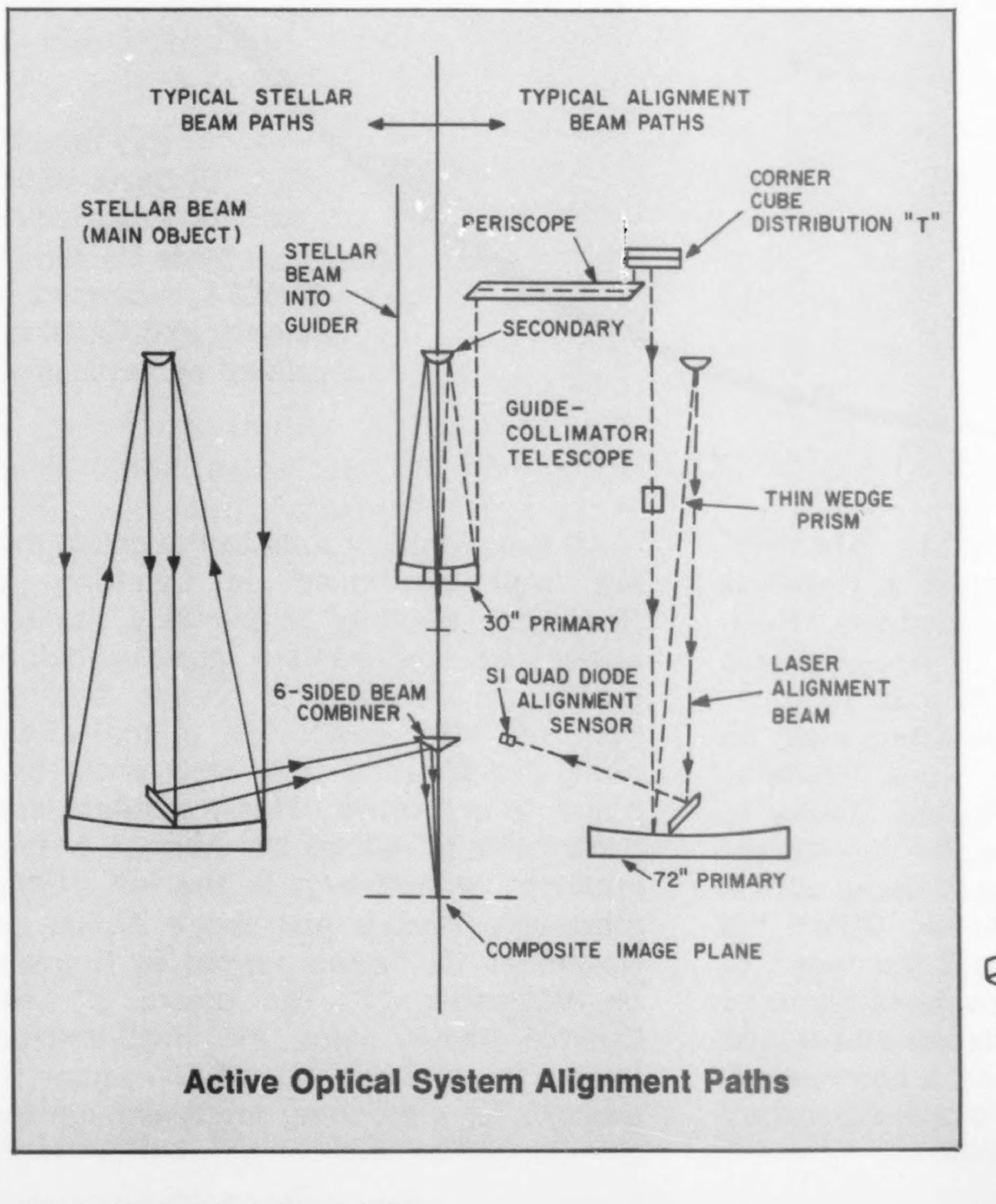
In 1972, the Smithsonian Institution and the University of Arizona jointly began work on the MMT after both discovered that they were working along parallel paths towards the same goal. The University's Optical Sciences Center began shaping the six primary mirrors from relatively lightweight blanks made by the Corning Glassworks and obtained from the U.S. Air Force. The University also developed the active optics and computer guidance systems. The Smithsonian prepared the site and constructed the telescope mount and the observatory building. The final cost of this unusual federal-state project was $8 million, about one-third the cost of an equivalent telescope of conventional design.

The MMT has been in use for only a short time, yet it already is returning valuable new information about the universe. One of the first studies undertaken with the MMT was an examination of what appeared to be twin quasars. Observations by the MMT have suggested that the light from a single distant quasar is being bent by a massive, non-luminous object between us and the quasar. Such a double image, produced by a gravitational lens effect, is predicted by Einstein's theory of general relativity. In addition, the new telescope appears to have discovered what may be a whole new class of stars—very short period, pulsating white dwarfs. These two important observations were made before the telescope was dedicated.

The MMT should have a long and fruitful life. It will turn its multifaceted eye towards planets, stars, and very remote objects such as clusters of galaxies. The MMT also was designed to work well in the infrared region of the electromagnetic spectrum. In fact, it is the largest telescope ever constructed to study this part of the spectrum. The MMT should supply valuable information about very young stars that are best seen at this wavelength.

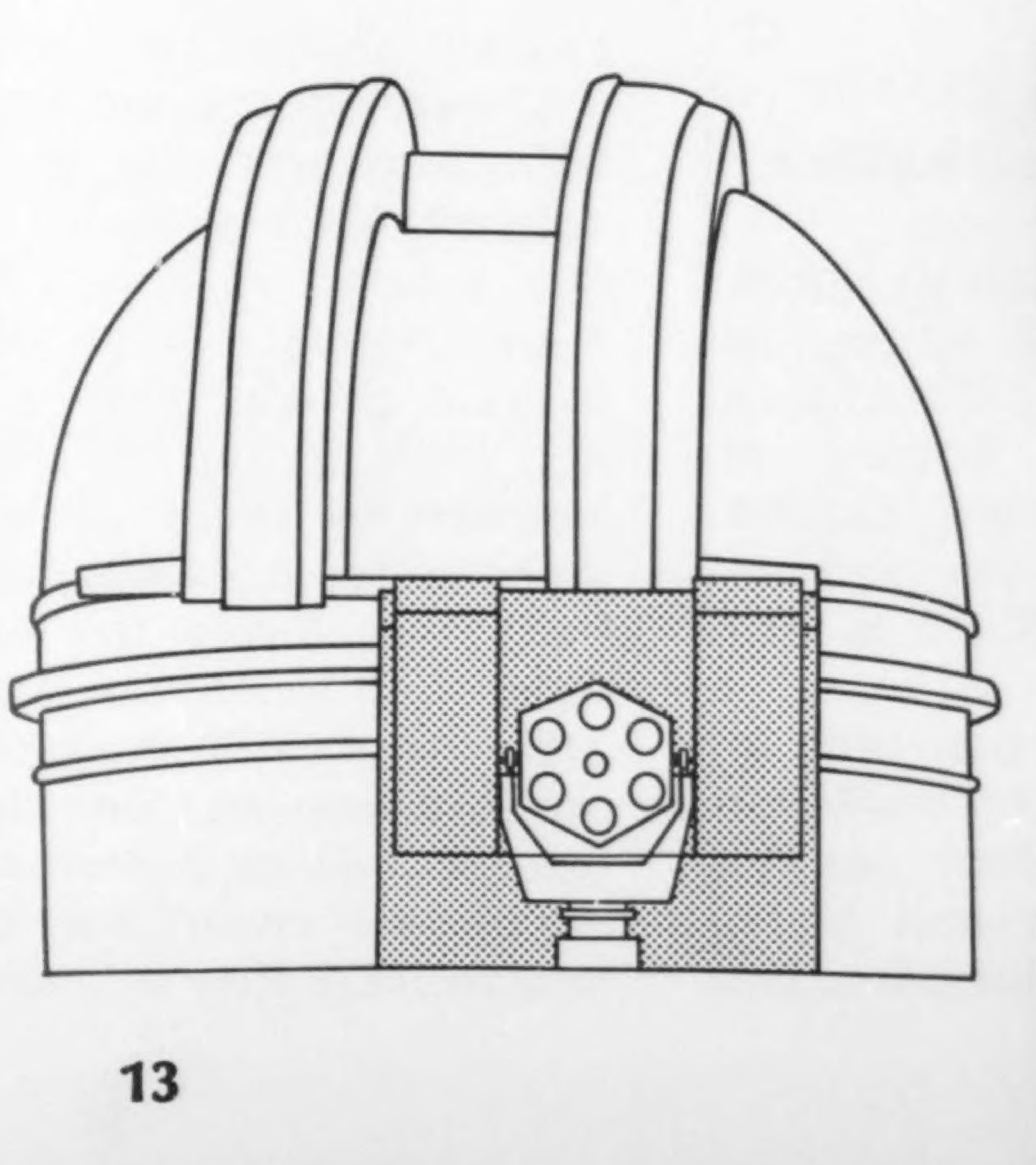
Other telescopes using the multiple-mirror concept are in the planning stages. Both the University of California and the Kitt Peak National Observatory have begun designs for similar instruments with 25.4-meter (1000-inch) equivalent diameters. Two multiple-mirror telescopes—a 1.2-meter (47-inch) test model, and a 25-meter (984-inch) operational telescope—are being developed in the U.S.S.R.

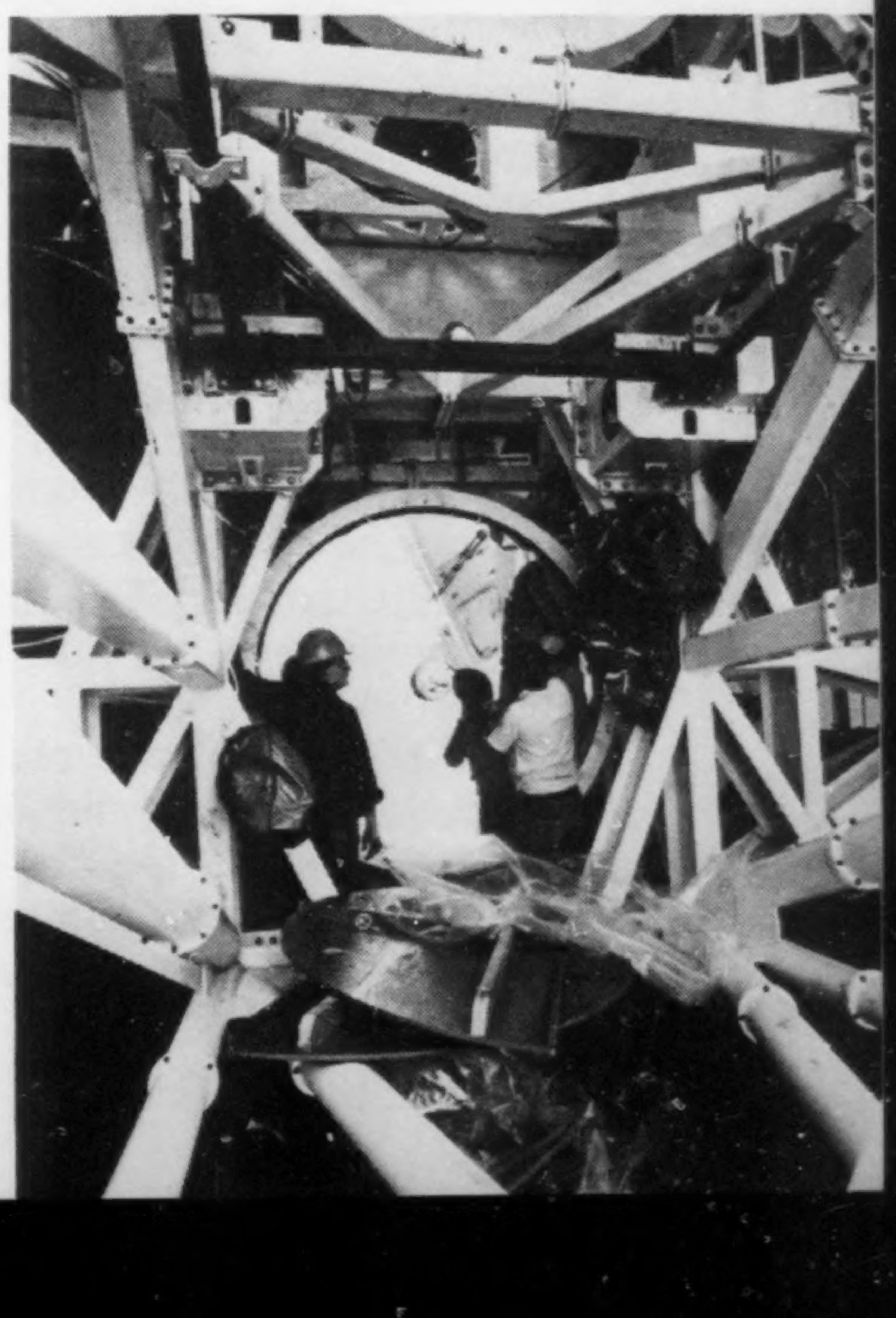
No matter who builds these new telescopes, they do so in the spirit of gaining a better understanding of the universe, how it came to be, and what course its future will take.


TYPICAL STELLAR BEAM PATHS
TYPICAL ALIGNMENT BEAM PATHS
STELLAR BEAM (MAIN OBJECT)
STELLAR BEAM INTO GUIDER
PERISCOPE
CORNER CUBE DISTRIBUTION "T"
SECONDARY
GUIDE-COLLIMATOR TELESCOPE
THIN WEDGE PRISM
30" PRIMARY
6-SIDED BEAM COMBINER
SI QUAD DIODE ALIGNMENT SENSOR
LASER ALIGNMENT BEAM
72" PRIMARY
COMPOSITE IMAGE PLANE

Active Optical System Alignment Paths

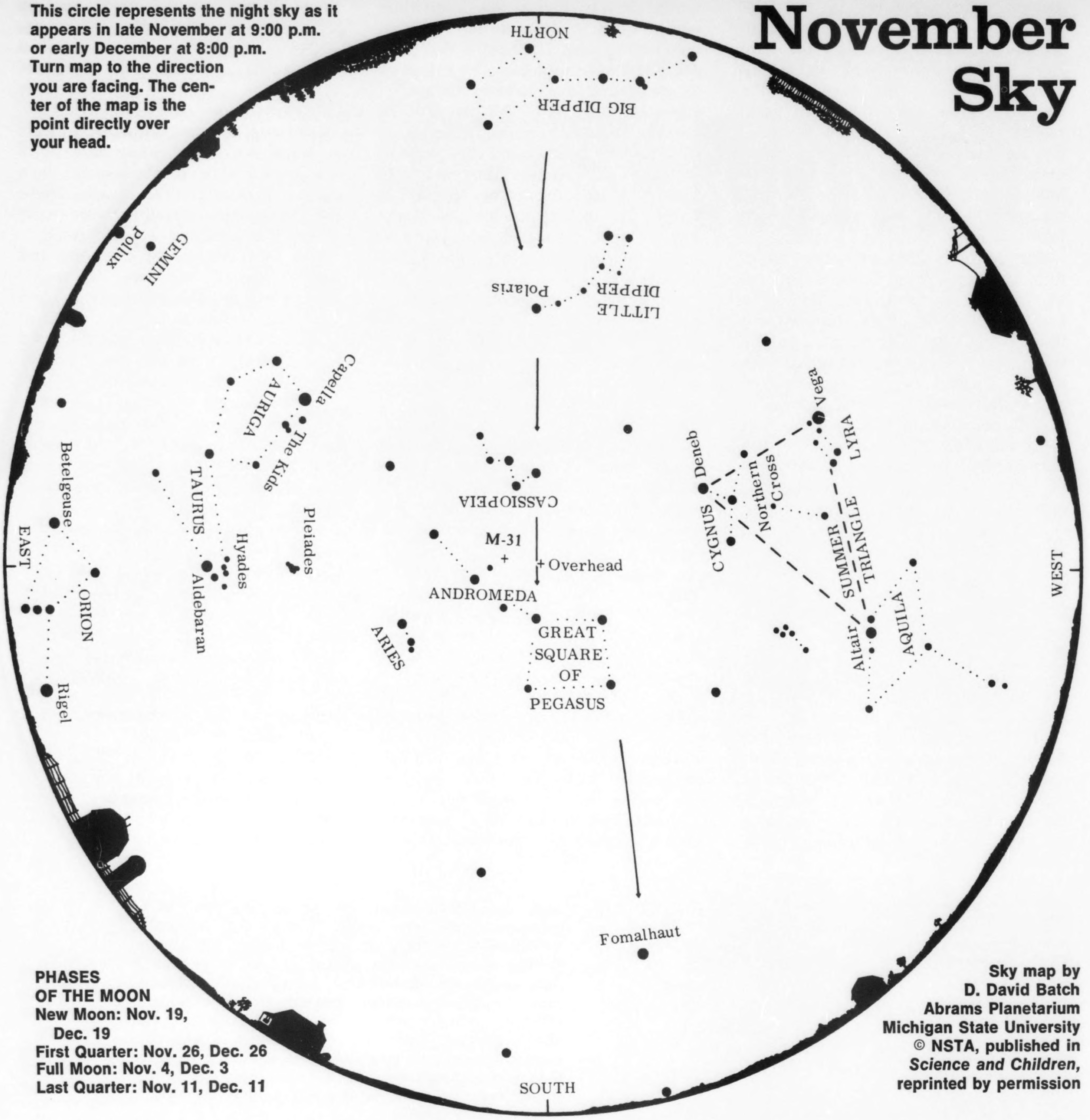
Left, the MMT's ingenious design, the first major advance in telescope design in more than a century, combines a multitude of mirrors, lasers, and sophisticated computer-driven electronics to focus visible light and infrared radiation from celestial objects. Right, technicians check one of the six 1.8-meter (72-inch) primary mirrors during construction. The MMT's compact optics and cubic housing make possible much smaller, less expensive telescope facilities than observatories like the 200-inch Hale Telescope, whose massive dome is outlined behind the MMT's shaded profile, center.





November Sky

This circle represents the night sky as it appears in late November at 9:00 p.m. or early December at 8:00 p.m. Turn map to the direction you are facing. The center of the map is the point directly over your head.


NORTH
BIG DIPPER
LITTLE DIPPER
Polaris
GEMINI
Pollux
Capella
AURIGA
The Kids
TAURUS
Hyades
Pleiades
Aldebaran
Betelgeuse
ORION
Rigel
EAST
CASSIOPEIA
M-31
+ Overhead
ANDROMEDA
ARIES
GREAT SQUARE OF PEGASUS
Deneb
CYGNUS
Northern Cross
Vega
LYRA
SUMMER TRIANGLE
Altair
AQUILA
WEST
Fomalhaut
SOUTH

PHASES OF THE MOON
New Moon: Nov. 19, Dec. 19
First Quarter: Nov. 26, Dec. 26
Full Moon: Nov. 4, Dec. 3
Last Quarter: Nov. 11, Dec. 11

Sky map by
D. David Batch
Abrams Planetarium
Michigan State University
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Science and Children,
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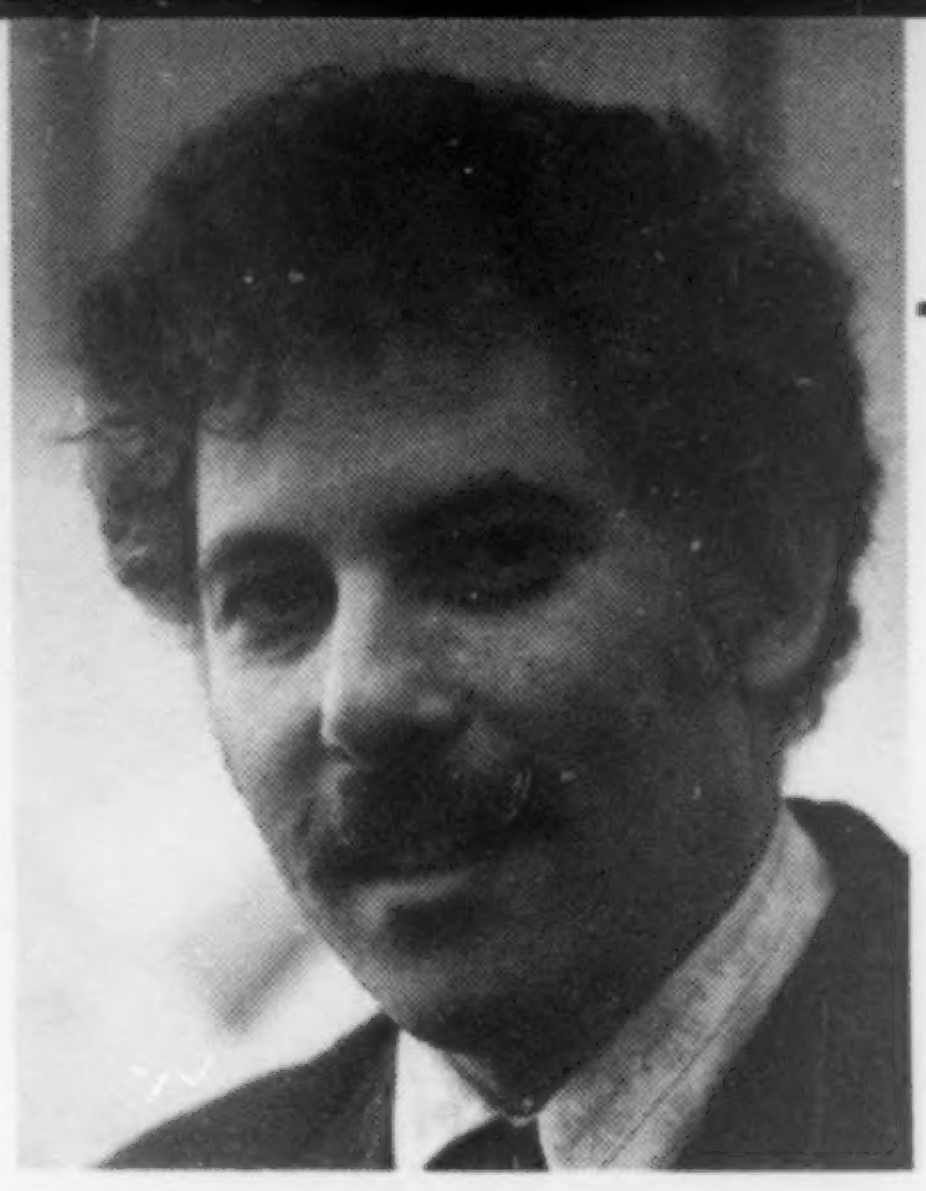
by T. H. Callen II
Production Specialist
Albert Einstein Spacearium, NASM

During late autumn's cold, clear nights, Orion and the bright stars of winter rise in the east. The celestial panorama is completed by the Great Square of Pegasus and other associated autumn stars to the south, while those of summer, represented by the Summer Triangle, set in the west.

In mid-November, two planets rising in the east shortly after midnight merit our attention. Located in Leo, they are, in order of brightness, Jupiter and Mars. Leo's blue-white star, Regulus, lies between these two visible planets.

Observing the motion of a planet is both easy and fun for students. Rust-colored Mars provides a fine example this autumn as it moves past Regulus. Mars' motion can be detected after an interval of less than a week; students may wish to map its progress relative to Regulus by using an eight- by eleven-inch cardboard frame with string cross-hairs that divide the space within the frame into quadrants. Hold the frame at arms' length with the crosshairs centered on Regulus. As the planet moves, its position can be plotted on a corresponding piece of paper, resulting in a planetary motion map after a few weeks.

All five planets visible to the naked eye are well positioned for viewing in December. Mercury is favorably situated above the southeastern horizon before sunrise on December 7. Venus, brighter than any star, stands low in the southwest, disappearing from view about two hours after sunset. Mars, Jupiter, and Saturn are all above the horizon before midnight, with Saturn to the left of the other two. Mars is just above Jupiter on November 13, having passed by Regulus on November 17. The moon, in Last Quarter phase, joins the thin triangle formed by the three planets December 11 through 13, a grouping pretty enough for any Christmas card.



OUTREACH

by Kerry M. Joëls

Chief, Education Division

Most teachers are familiar with Bloom's taxonomy, the accepted classification under which goals are written for American school systems. Many teachers easily write learning objectives for cognitive and affective classroom activities, but the objectives for psychomotor activities usually are written only for the gymnasium floor. However, physical development is part of a child's total maturing or growing-up process and is a domain of learning that shouldn't be overlooked in the classroom. Aerospace education can be used as a unique and effective curricular supplement to blend classroom activities and the acquisition of both gross and fine motor skills.

Gross motor skills, a major element of the psychomotor domain that youngsters use to control body movements in a given space, are not unlike those developed by the aerobatic pilot who must learn orientation and how to control an aerobatic aircraft in a given space. Flight-related psychomotor activities in the elementary classroom can provide a means of teaching gross psychomotor skills in ways young students find exciting.

Simple elementary activities might include the imitation of basic flight maneuvers, such as takeoffs, landings, banked turns, climbs, and dives. Students also can try to imitate aerobatic maneuvers, such as loops (somersaults) and rolls, as floor exercises. Outside the classroom, students may wish to try similar "aerobatic" maneuvers on a trampoline or from a diving board.

Aerobatic teams like the Blue Angels and the Thunderbirds depend on timing and a precise sequence of movements performed simultaneously to thrill onlookers. Perhaps your students can imitate an aerobatic team show by combining a series of exercise movements and performing these movements simultaneously. Begin by instructing the students to skip and hop in pairs. It takes psychomotor skills to accomplish this task.

Younger students might even like to participate in body movement exercises by describing alien beings and then mimicking their imaginary body movements.

Piloting—whether in light aircraft or spacecraft—can also require intense concentration on finely tuned psychomotor coordination and learned skills. Other aerospace careers involving fabrication, maintenance, or design demand both large and fine muscle coordination, such as hand-finger and hand-eye coordination. The fine skills of drawing, design, assembly and maintenance can be supplemented by aerospace activities such as modeling, drafting, or constructing model aircraft and rockets.

Aerospace education offers teachers new ways of looking at existing curricula. By correlating psychomotor skill development with aerospace activities, aerospace education makes possible a complete curricular supplement.

Free Presentations on Aviation and Space Available

NASM has trained nine educators to give presentations in their communities on the history and significance of aviation and space.

The educators participated in an experimental Regional Resource Person Training Session held in late July at NASM in Washington, DC. The program, new this year, included an intensive course in the history of aviation and space and a review of teaching methods. The educators have returned to their communities where they will teach other instructors the history of aeronautics and astronautics and ways to integrate these subjects into the school curriculum.

These Regional Resource Persons will make free presentations to teachers, students, and to the general public:

Darrell E. Asbury, Morgantown High School, Morgantown, W VA;

G. Courtney Chapman, Ohio State University, Columbus, Ohio;

Walter Dinteman, Camden County College, Blackwood, NJ;

Virginia Ellett, Mathematics and Science Center, Richmond, VA;

Dr. Fred Hofkin, School District of Philadelphia, Philadelphia, PA;

Sister Jean Margaret Kaindl, Mother Guerin High School, River Grove, IL;

Richard Rooney, New Castle County School District, Wilmington, DE;

Lockhard Smith, Jr., Wentworth Institute, Boston, MA; and

Sherman Taffel, Lake Clifton Senior High School, Baltimore, MD.

For more information on presentations in your community, contact the Regional Resource Person in your area. For further information on the Regional Resource Person Program, contact Janet Wolfe, Education Division, National Air and Space Museum, Washington, DC 20560.

Special Presentations Calendar

The NASM Special Presentations Calendar is issued quarterly and is available without charge to the general public. To be put on the mailing list, send your name and address to Quarterly Calendar, Presentations Division, National Air and Space Museum, Washington, DC 20560.

ILLUSTRATION CREDITS

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Answers to Aerial Photography Interpretation Quiz, Pages 6-7:

1. The Soviet Cosmodrome from which Sputnik and Yuri Gagarin were launched.

2. The Kremlin, Moscow; note fake structures painted in square and within the Kremlin wall, plus shapes of shadows.

3 and 4. MRBM missiles and support equipment in Cuba during the 1962 Cuban Missile Crisis.

5. The bridge over the River Kwai, Thailand; note the prisoner-of-war camp, left center.

THINK ALONG WITH THE AIRCRAFT DESIGNERS

What makes a good aerobatic airplane?

by Brig. Gen. Benjamin S. Kelsey (USAF, Ret.)
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A good aerobatic airplane is a compromise, as are all aircraft. The basic design goals are strength and maneuverability.

Unlimited category aerobatic airplanes usually are designed to withstand flight stresses of up to nine positive g's (i.e., nine times the force of gravity, pushing the pilot into the seat) and six negative g's (pushing the pilot against the seat belt and shoulder straps) or more.

For maximum maneuverability, the aircraft should have extremely responsive controls, compact design, and neutral stability (i.e., neither resist nor exaggerate the pilot's control movements). To fly as easily inverted as upright, the wing should have a symmetrical airfoil and little or no dihedral (the vee shape of the wing seen head-on, which provides upright roll stability).

Four-time National Aerobatic Champion Leo Loudenslager (below) placed third in this year's National Aerobatic Championships in his unique Laser 200 monoplane. Highly modified single-place Pitts Special S-1S biplanes, similar to the two-place S-2A (above), dominated the contest. Designed specifically for unlimited aerobatic competition, these airplanes represent different approaches to the same goal—the ultimate aerobatic airplane.

In competition, maneuverability also means completing as many maximum-difficulty maneuvers as possible without flying out of the competition "box." The airplane must not lose speed too quickly in vertical ascending maneuvers, nor gain it too quickly in descending maneuvers. A low-drag design will climb well, but accelerate too quickly in a dive. The solution seems to be high power with low weight.

By eliminating such "frills" as electrical and hydraulic systems, lights, engine starter, and all unnecessary instruments, the designer pares weight from the aerobatic airplane.

Fixed landing gear offers a weight savings over retractable wheels, and the extra drag is an advantage in diving maneuvers. The tailwheel configuration weighs less than a nosewheel design. Airplanes with tailwheels often are more difficult to land than those with nosewheels, but most aerobatic designs sacrifice good ground-handling for aerial performance.

To keep the engine running in all flight attitudes, inverted fuel and oil systems are a must.

Aircraft designers have been debating since before World War I whether biplanes or monoplanes are better suited to aerobatic refinement. In the arena of competition aerobatics, the battle rages on.

It is easier to design great strength into the biplane, with its crisscrossed external bracing wires, than into the internally braced cantilevered monoplane wing. The extra drag of the biplane's struts and wires are a disadvantage in climbs, but an advantage in dives.

Airplanes with short wings generally roll faster than those with long wings. Biplanes can be designed with shorter wings than monoplanes with the same wing area, and can be fitted with ailerons on both upper and lower wings.

Monoplanes displaced biplanes decades ago in military and airline flying, where high speed is more important. But in the specialized world of competition aerobatics, the biplane—which may *look* old-fashioned—still may be the best all-around performer.

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